

ASTRONOMY

August 1987

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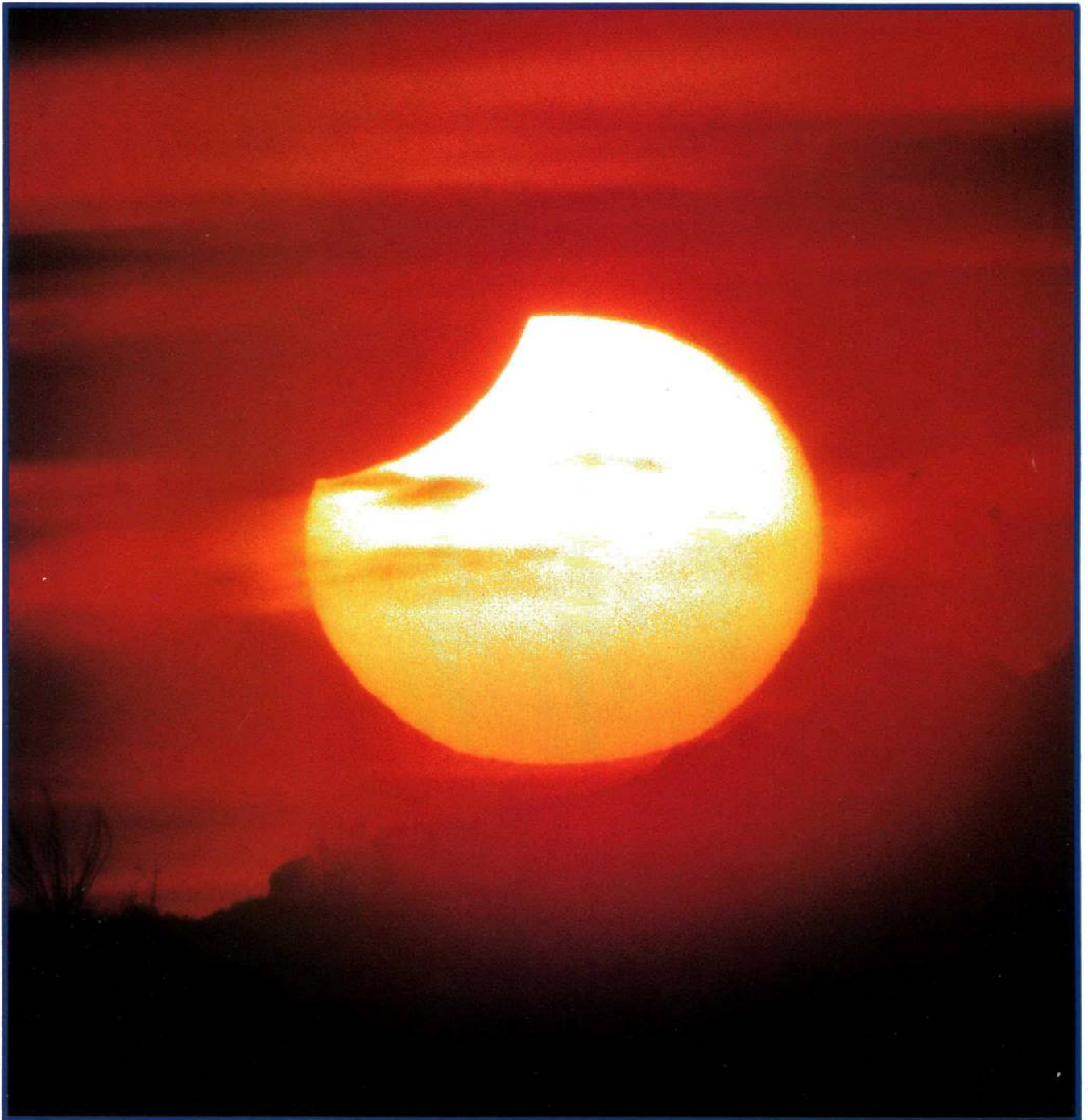
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The Space Junk Threat

How to Photograph a Star Cluster

Inside the World's Largest Radio Telescope

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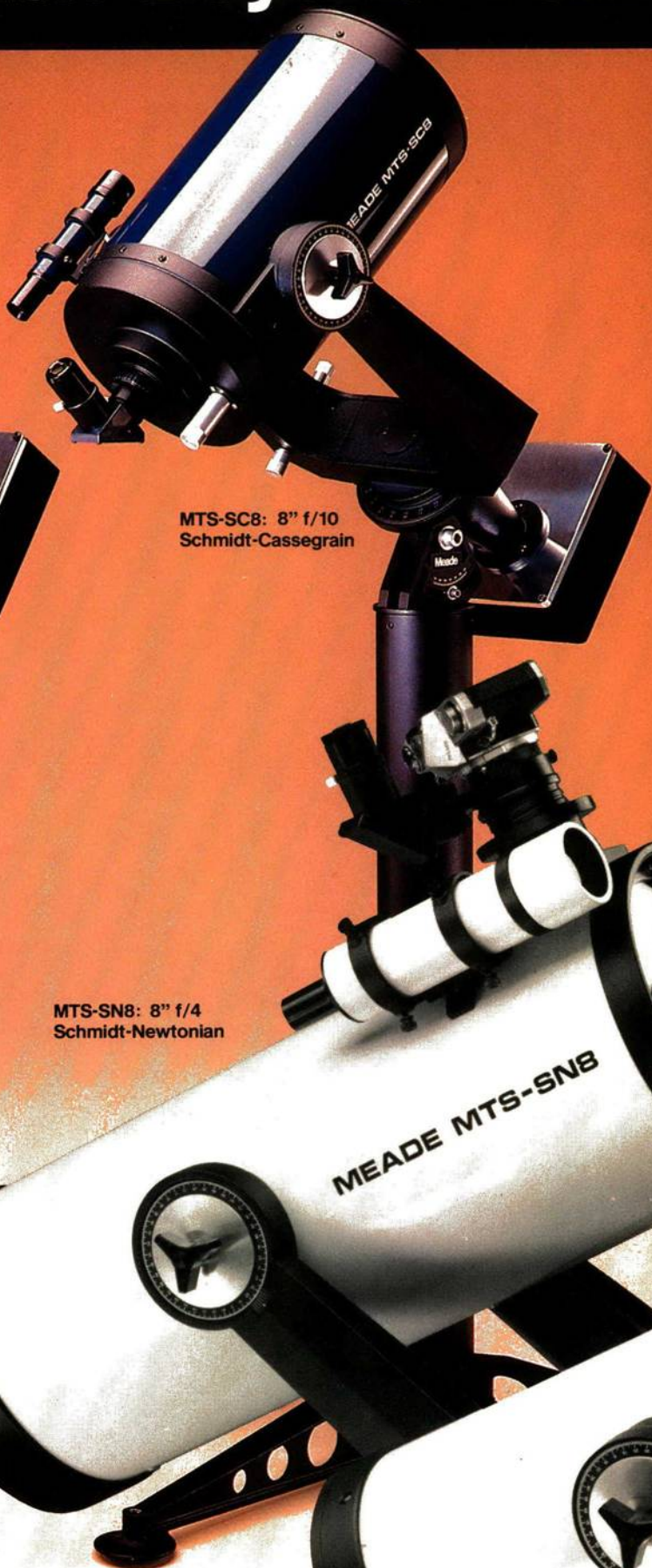
Previewing the March 1988 Eclipse



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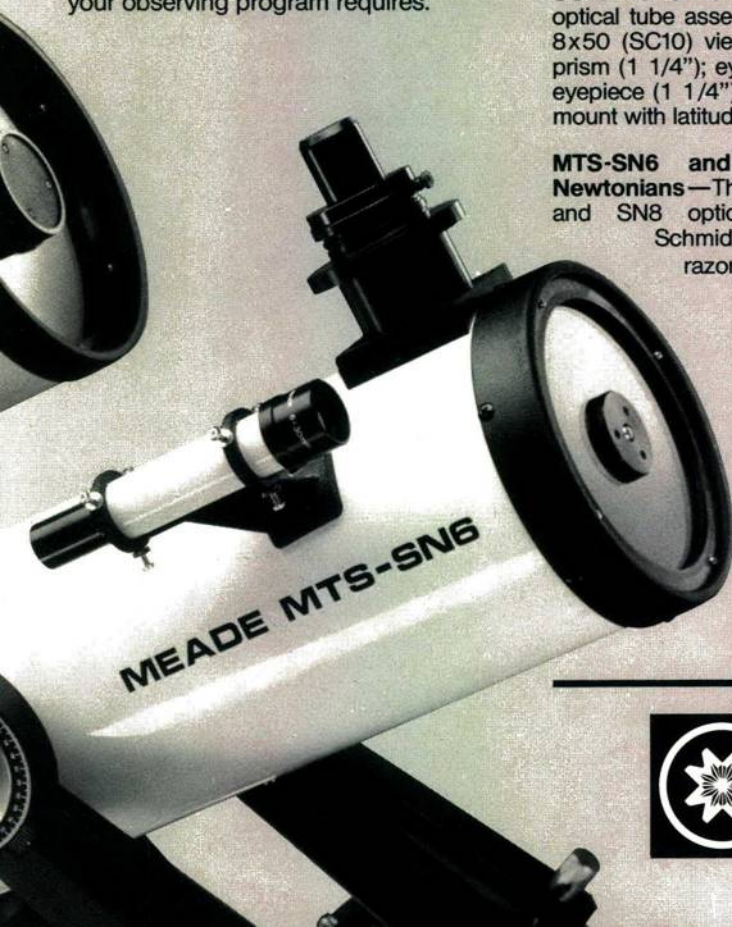
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Cassiopeia

Cover: The Sun is partially eclipsed by the Moon on December 13, 1974. It's not too soon to plan your trip to Southeast Asia to see the March 1988 eclipse. Photo by Ernest W. Piini. These pages: The Very Large Array's giant antennas make the VLA exceptionally productive. An inside look at the VLA begins on page 14. Photo by Robert Burnham.

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THE IMPENDING CRISIS OF SPACE DEBRIS

by
Joseph A.
Lovece

Manmade orbital debris presents a serious hazard to satellites and manned space vehicles and could adversely affect ground-based observations of the sky.



The collision of a segment of an exploded rocket stage with the Hubble Space Telescope would have catastrophic results. Painting by Jim Hervat.



Jeffrey
© 87



The satellite was blown into a thousand pieces years ago during an antisatellite weapon test. Since then the tiny fragments of metal and flecks of paint from the destroyed satellite have been circling the Earth at a speed one hundred times faster than a rifle bullet, untracked by radar and on unknown trajectories.

One marble-sized piece of metal seems alone and insignificant in the vastness of space 350 miles above Earth's surface. But it is neither alone nor insignificant because, emerging from Earth's shadow, the United States' only working x-ray telescope is on a collision course with the fragment.

Silently the piece of space shrapnel bores through the onboard computer, violently splintering off pieces of housing and electronics and flinging them out into space. On Earth the astronomer's instrument panels register an inexplicable loss of transmission.

It hasn't happened yet, but it could. In fact, there is mounting evidence that orbiting satellites and manned vehicles have experienced collisions, though these impacts have not been too serious. Nevertheless, one can easily imagine the above scenario involving the mirror of the Hubble Space Telescope or an astronaut working in the cargo bay of the Space Shuttle.

The space around our planet is polluted. The North American Air Defense System (NORAD) currently tracks 6,194 radar-trackable objects — baseball sized and larger — in terrestrial and interplanetary orbit, only 300 of which are operating satellites. An estimated 40,000 golfball-sized pieces are not tracked, along with billions of smaller pieces. The debris includes expended rocket stages, rocket panels, fragments from exploded satellites, nuts and bolts, and even hand tools that have slipped from the gloves of space-walking astronauts.

"The growth factor is [such] that debris will double by the 1990s," says Donald Kessler, NASA orbital debris specialist at Houston's Johnson Space Flight Center.

Origins of Space Junk

Without a doubt, most space debris comes from explosions of spent rocket stages and satellites. Approximately eighty explosions have been caused by a combination of the combustion of spent rocket casings and deliberate explosions for space weapon testing.

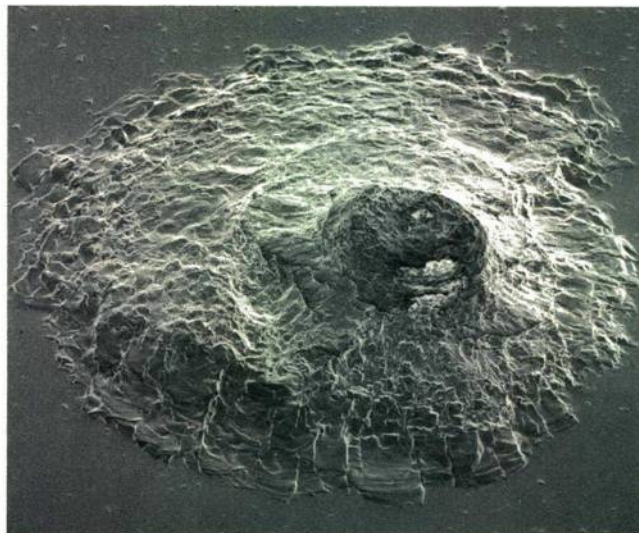
Unplanned explosions of rocket stages can occur years after launch. Some fifteen Soviet Proton and U.S. Delta and Titan rocket shrouds are known to have burst spontaneously while in orbit. Karl Henize at the Johnson Space Center says that apparently the thin walls separating different fuels in spent rocket stages corrode, which allows the fuels to mix and explode. According to Kessler, some Delta shrouds lay dormant for three years before igniting. And recently an Ariane rocket stage exploded after nearly a year in orbit, spewing out millions of pieces.

Deliberate explosions in space have been occurring since mankind's entrance into space. In the late 1950s the United States exploded atomic warheads in the upper atmosphere and in low orbits. And for a generation U.S. and Soviet antisatellite and ballistic missile defense tests in low Earth orbit have injected nearly 10 million pieces

of debris into low and high orbits.

Although the Soviet Union initiated a unilateral moratorium on antisatellite testing in June 1982, the U.S. continued testing. On September 13, 1985, a functioning solar research satellite, Solwind, was destroyed by an experimental missile (see "Solar Research Satellite Destroyed in Missile Test," *AstroNews*, January 1986). Apparently the Air Force decided the satellite had outlived its usefulness. NORAD data show that the destruction of the Solwind satellite left a three hundred mile-long cloud of

**"There is roughly a 1 percent chance of [the Hubble Space Telescope] being destroyed by debris during its lifetime."
— Michael Shara, Space Telescope Science Institute.**



In June 1983 a postage stamp-sized paint flake made a 2.4-millimeter-wide crater in the window of the Space Shuttle Challenger. The energy of the impact was equivalent to that of a bowling ball going 60 miles per hour.

three hundred trackable pieces and countless smaller fragments. After this test, however, Congress prohibited antisatellite tests against objects in space. Nevertheless, the most recent deliberate explosion in space occurred in September 1986, when two satellites were blown up as part of a Strategic Defense Initiative test.

Even if no further refuse was generated by intentional or accidental explosions, the flurry of fragments already in orbit might spawn more debris. NASA scientists believe the great velocities at which space particles collide (about 8 to 10 kilometers a second) could be destructive enough to generate hundreds or perhaps thousands of additional particles, depending on the size of the impacting fragment. The proliferation of these particles could snowball into a chain reaction of collisions with other satellites or particles, and the result might be a debris belt around the Earth. Should this belt tear into a discarded satellite, still more debris would be generated, as would the potential for greater destruction.

A case in point was reported in the media recently when the Soviets dumped three thousand pounds of old nuclear-powered satellites in a 600-mile-high orbit.

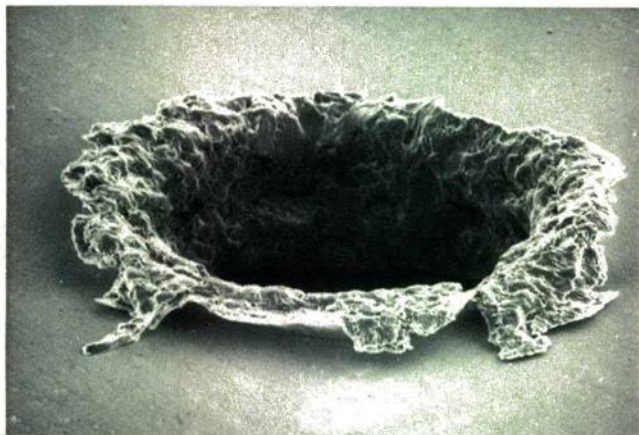
"A hypervelocity collision with a spent Soviet nuclear

Opposite page: Particles from exploded satellites and fuel tanks, jettisoned rocket panels, hand tools, nuts and bolts, and expended rocket stages, like the Saturn S-IVB stage seen in this photograph, constitute much of the flotsam and jetsam of the space age. NASA photo.

reactor may produce as many as one million particles, [each] with a diameter of one millimeter or more," says Nicholas Johnson, a Teledyne-Brown Engineering advisory scientist.

Contrary to popular belief, space is not self-cleaning. Although objects in low Earth orbit are more susceptible to atmospheric drag, particles in a 180-mile-high orbit will take days or months to re-enter the atmosphere. But the higher the altitude, the longer the particles remain in orbit. A marble-sized piece orbiting at 300 miles will last at least

"It is conceivable that a debris population will be created which will make the near-Earth environment unusable for any extensive space program." — Robert C. Reynolds in the *Journal of Spacecraft and Rockets*.



Scientists at the Johnson Space Center in Houston found an average of six holes per square foot in the aluminum louvers of the Solar Maximum Satellite, which apparently were the result of high-velocity impacts with orbiting paint flakes. The hole in this microphotograph is about 1 millimeter across. The louvers are made of two layers of aluminum that are each nearly one-and-a-half millimeters thick. NASA photo.

a year. At 500 miles it will remain for thirty years, and at 800 miles it may linger for up to three hundred years. And as long as it remains in orbit, it threatens working satellites and astronauts.

The Vulnerability of Science Missions

At 300 miles, the typical altitude for space stations, orbiting telescopes, and other scientific satellites, you are "definitely in a debris environment," says Kessler. With their exposed apertures and scientific equipment, space telescopes are especially vulnerable to collisions.

NASA has been especially concerned about debris since June 1983, when a piece of scrap the size of a postage stamp cracked the windshield of the Space Shuttle Challenger. Other satellites reported to have been battered by space junk include the Soviet Kosmos 1275, the European GEOS-2, and a U.S. balloon satellite.

"It is conceivable that a debris population will be created which will make the near-Earth environment unusable for any extensive space program," Robert C. Reynolds recently wrote for the *Journal of Spacecraft and Rockets*.

Graphic evidence of the damage that can be wrought by seemingly innocuous space particles was discovered

in 1984 after Challenger astronauts retrieved the ailing Solar Maximum Mission satellite after it had spent four years in a 350-mile-high orbit. Microphotographs of the satellite's louvers revealed thousands of "craters" in the aluminum exterior. The biggest hole was slightly less than a millimeter in diameter. Johnson Space Center used this data to estimate the number of particles per square meter per time, or flux curves, for space debris and concluded the amount was the same as for micrometeorites.

The Hubble Space Telescope, scheduled for launch in 1988 for a projected 17-year lifetime, may not survive to carry out a full mission. According to Michael Shara, an assistant astronomer at the Space Telescope Science Institute in Greenbelt, Maryland, "There is roughly a 1 percent chance of it being destroyed by debris [during its lifetime]." For a billion-dollar enterprise like the Space Telescope, such odds are not attractive. Taking into account the telescope's low Earth orbit, its cross section of 172 square feet, and extrapolating the Johnson Space Center's debris-flux estimates, Shara and Johnson produced the above probability estimate for collisions with objects 5 to 10 millimeters in size. Their work was described in a paper for the August 1986 issue of *Publications of the Astronomical Society of the Pacific*.

A collision with a 10-centimeter or larger object would probably destroy the Space Telescope. In addition, Shara and Johnson believe there is a 0.1 percent chance of collision with a 1-meter object. Unlike many satellites, the Space Telescope has no thrusters to maneuver itself out of the way of an oncoming piece of debris, so tracking space junk of this size doesn't help. Says Shara, "If they know a couple of days ahead that a large piece of debris is going to hit the telescope, I don't want to know about it."

Small particles will also affect the Space Telescope's performance. Paint flakes and dust hitting the mirrors will degrade the telescopes' imaging ability. In addition to pits in the mirror caused by direct impacts, tiny particles on the mirrors would scatter rather than reflect light; the "background noise" would be like fog on a photographic plate, reducing the telescope's ability to observe faint objects.

Effects on Ground-based Astronomy

Viewing the stars through Earth's mantle of air has always been like peering through a fishbowl. But in the future, looking into space could be more like looking through a chain-link fence if manmade orbital debris continues to multiply at its present rate.

Large objects, like the Space Shuttle and the Soviet space station Mir, can easily be seen with the naked eye. Others are fainter than the eye can detect, but not too faint for sensitive photographic emulsions. Still, most satellites and space debris in low Earth orbit are visible only a few hours after dusk or before dawn, so they aren't too much of a problem for ground-based observatories.

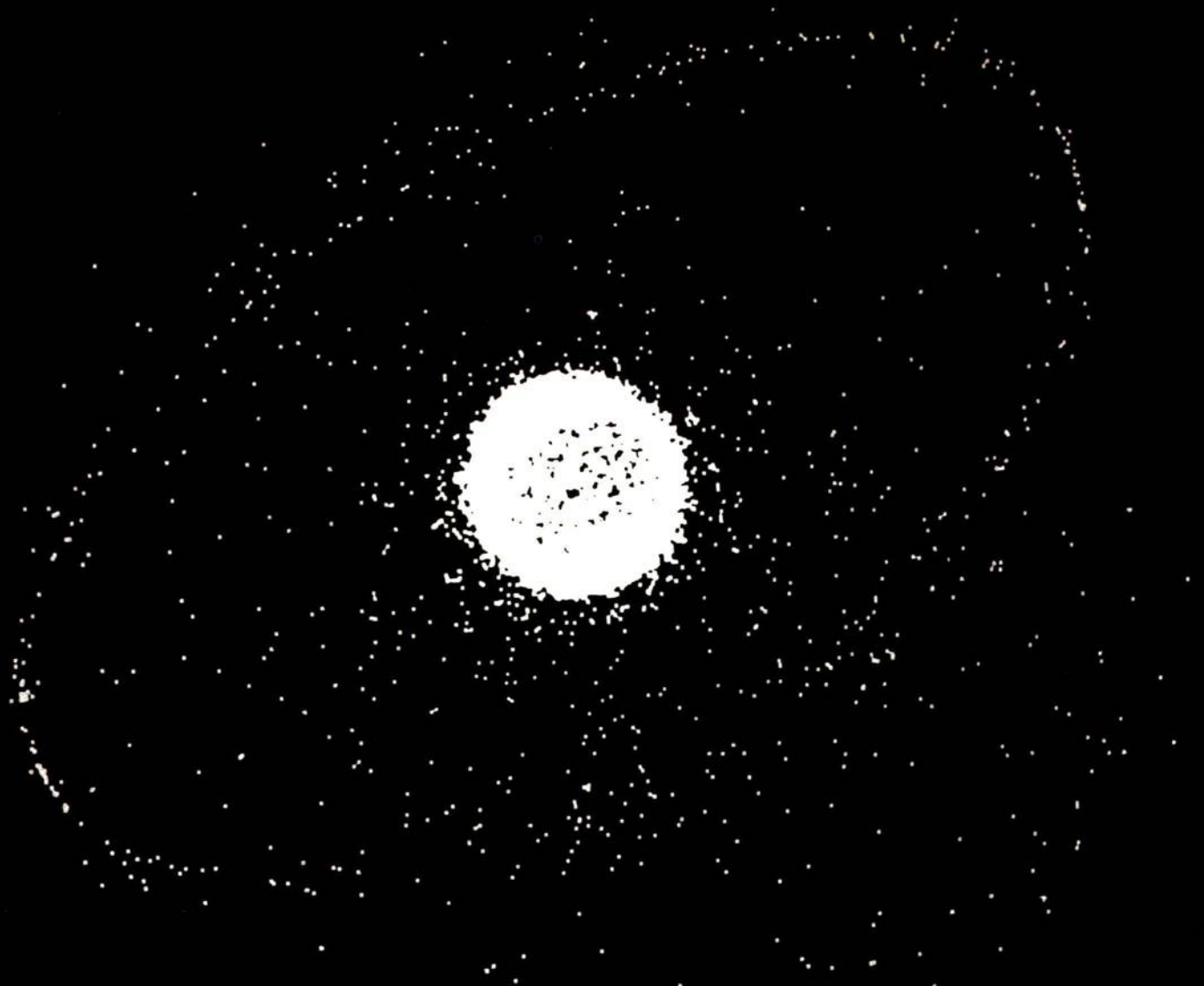
But pieces of broken satellites and spent rockets in geostationary orbits 22,300 miles above Earth will pose a more serious problem, because the clutter could be visible most of the time and have an infinitely long decay period. Although Kessler estimates that debris in geostationary orbits won't be a problem for another twenty years, astronomers are already bemoaning the possibilities. "One can scarcely imagine something worse for astronomy!" says Dr. Russell Cannon, the new director of the Anglo-Australian Observatory in Epping, Australia.

The seriousness of space debris for ground-based



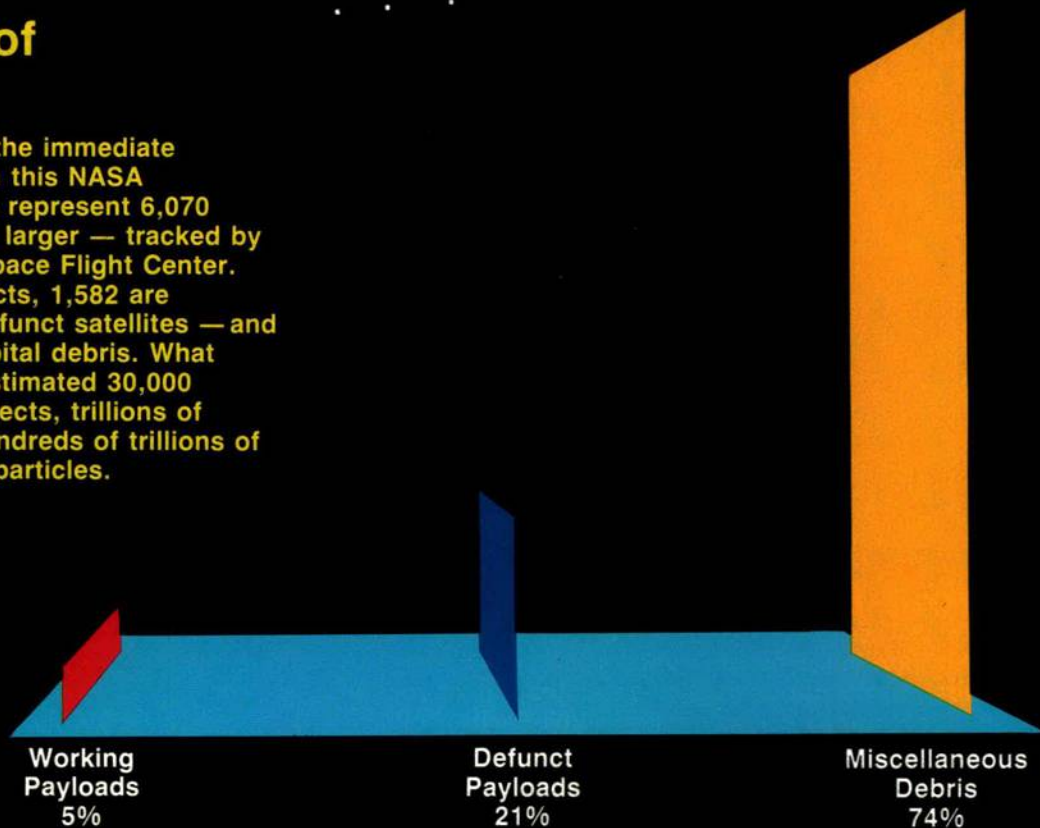
Near-Earth Space Debris

This computer graphic shows the locations of thousands of satellites, spent rocket stages, and breakup debris in low Earth orbit. This image was produced by Teledyne Brown Engineering, one of many firms assisting NASA in orbital debris studies.



Keeping Track of Space Debris

The cluttered space within the immediate vicinity of Earth is shown in this NASA computer graphic. The dots represent 6,070 objects —softball sized and larger — tracked by NORAD and the Goddard Space Flight Center. Of the total number of objects, 1,582 are payloads — working and defunct satellites — and 4,488 are miscellaneous orbital debris. What cannot be tracked are an estimated 30,000 marble- to softball-sized objects, trillions of paint flakes, and tens of hundreds of trillions of aluminum oxide dust-sized particles.



astronomy depends on the kind of research astronomers are doing. To most scientists space debris is an annoyance that is a "completely negligible problem at present," says Robert Huntington, an astronomer at the U.S. Naval Observatory in Washington, D.C. Examining one bright item in the sky at a time, for example, is no problem. Spectrographs, which use a narrow light entrance and a slow focal ratio operating between $f/8$ and $f/11$, for instance, shouldn't be affected. And fields of view under 25 square degrees rarely pick up any satellites at all.

But if astronomers are mapping large sections of the sky or photographing very faint objects and making long exposures, satellite trails may appear on the plates. "Field of view matters because a wide field will obviously accidentally capture more satellites," says Cannon. Prime victims are observations by telescopes with short focal lengths used for long exposures such as the Schmidt telescopes at the Palomar Observatory in California and the Anglo-Australian Observatory, which are both $f/2.5$ and cover wide fields.

Optical astronomers differ in their views of how debris affects their work. "We aren't rejecting plates because of satellite trails. They're mostly a cosmetic defect which doesn't compromise the scientific value," says Robert Brucato, assistant director of Palomar Observatory, referring to the ongoing Palomar Sky Survey. If a trail crosses over key data on the plate, the exposure may be rejected and reshot, "but only in very special circumstances," he adds.

Cannon has had to deal with this problem. "Yes, we have had to reject plates," he says. "We have had on occasion seven trails on a plate. At that level they begin to affect seriously the science one can do, since many galaxies will be crossed and their images rendered useless for quantitative surface photometry." He mentioned one photograph in which every one of a half-dozen galaxies of interest was spoiled by a trail.

Debris can also disrupt radio astronomy. Small, reflective particles can interfere with radio transmissions, wiping out whole bands of the spectrum at a time. Astronomers were given a preview of this problem in 1961 thanks to an Air Force test called Project West Ford. Originally called the "Needles Project," it launched billions of tiny copper needles into orbit to create a dipole belt around the Earth to act as radio-wave mirrors. The astronomical community vehemently protested. Peter Boyce of the American Astronomical Society says the test was fortunately only a temporary problem. The needles were supposed to re-enter the atmosphere in early 1966, although Irwin Shapiro, director of the Harvard-Smithsonian Center for Astrophysics, says a few clumps may still be in orbit.

Can Space Be Cleaned Up?

Space debris will soon become a serious problem if nothing is done about it. Though measures can be taken to prevent further space "littering," NASA and some aerospace companies are wondering if the clutter presently encircling Earth can be swept up. One interesting proposal is the Trash Removal and Satellite Hauler-1 (TRASH 1). Marshall Kaplan of Spacotech Incorporated wants to form a satellite salvage company to market this unmanned refuse-removal satellite.

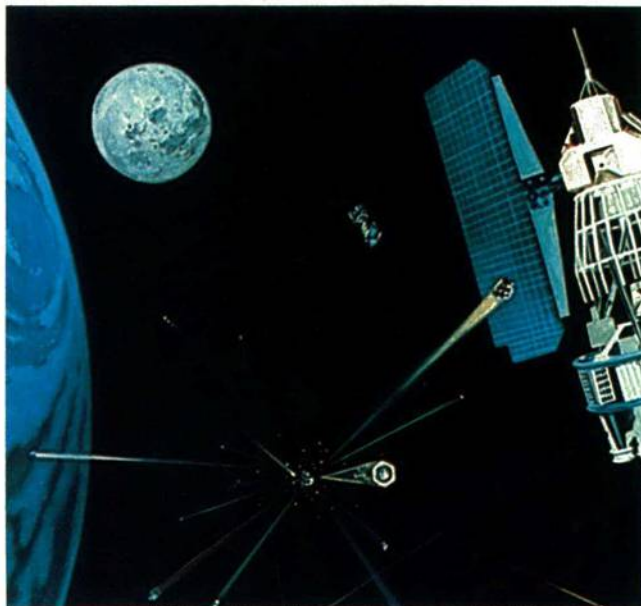
A more recent proposal is a debris catcher with a "scoop" miles in diameter. Another device, designed to capture tumbling satellites or other debris, is being studied at NASA's Marshall Space Flight Center.

"We sit around at coffee time and come up with great ideas [for cleaning up space], but none of them seems

practical," said Karl Henize of the Johnson Space Center. Debris prevention, on the other hand, appears more practical and cost-effective. The Air Force, for instance, wants to use more "disposal orbits" in low Earth orbit and techniques to quicken orbital decay and re-entry. Satellites are also becoming more modular, which eliminates the need for exterior nuts and bolts. And a new NASA operational procedure that uses up all rocket fuel is eliminating the problem of exploding rocket casings.

What more can be done? "Right now I would strongly

A ban on deliberate space explosions would be difficult to achieve because it is a political and not a scientific decision.



As the roster of orbital debris grows, astronomers will have to accept the possibility that satellites may be prematurely disabled or destroyed by impacts. NASA illustration.

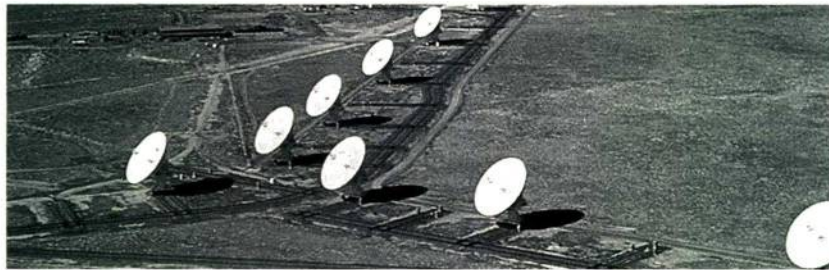
recommend some kind of international agreement on preventative measures," says Kessler. Space-faring nations could agree to implement various preventative steps rather than depend on everyone's good intentions not to litter space. Unfortunately, a ban on deliberate space explosions could be difficult to achieve because it is a political rather than a scientific decision. In any case, without an international space-debris agreement, unilateral efforts will be pointless.

If the space around Earth continues to fill up with manmade clutter, sending aloft delicate scientific instruments will become increasingly risky and, if disaster strikes, very expensive. The premature loss or debilitation of a mission like the Hubble Space Telescope would be a tragedy of inestimable proportions, because there is no way to evaluate how much knowledge would be lost or how long it would take to get another scope into orbit. Clearly, for space science, that is a price too high to pay.

Joseph A. Lovece is assistant editor of Military Fiber Optics News and a freelance writer based in Washington, D.C. His articles have appeared in Technology Review and Mother Jones.



The Telescope That Never Sleeps



The Very Large Array radio telescope with its twenty-seven antennas may be the most productive scientific instrument on Earth.

by Lys Ann Shore

It's a fifty-mile commute from Socorro, New Mexico, to the Very Large Array radio astronomy observatory, and the buses leave early. Most of the 120-plus VLA staff members live in Socorro, so the twice-daily ride with their colleagues down U.S. 60 has become the axis of their daily routine. Some have been riding the blue-and-white VLA buses since the mid-1970s, when the observatory was being constructed.

The trip is uphill all the way, from the 4,600-foot altitude of Socorro through canyons, grazing lands, the tiny, once-bustling cattle town of Magdalena, and a piece of the Cibola National Forest, to the 7,000-foot elevation of the plains of San Agustin. The array comes into view as the buses top a rise beyond the forest. Spread out ahead is a broad, brown plain ringed with mountains and, strung across the plain so far they fade indistinguishably into the distant horizon, are the gleaming white dishes of the VLA.

The antennas stretch in three directions, dotting the landscape in the shape of a huge "Y." The movable array can be in any one of several configurations; at the array's most elongated configuration, the twenty-seven dishes run 13 miles down two arms of the "Y" and 12 miles down the third. In that configuration you must strain to see the entire array, and even then your vision becomes confused by the distance and the curvature of Earth.

An ancient, dry lake bed, the plains of San Agustin haven't changed much in the past hundred years. One early settler recalled how "no sign of human habitation greeted us as we topped the divide west of [Magdalena] and gazed across at the blue bank of haze that blanketed the western sky — the Datil Mountains . . . forty miles away. Between us and the Datils the road unrolled in a long, straight thread across the San Augustine [sic] Plains . . . fifty to seventy miles [across]. Rimmed by the Magdalenas, the San Mateos, the Datils, and the Gallinas, the plains form a vast saucer. . . . It was while we trudged behind the lurching wagon that an unforgettable sight

burst upon us. Off to the left where the San Mateos formed the southern rim of the plains, the dry earth appeared magically to have changed to tawny water, which rose and fell in long undulating swells."

The "tawny water" turned out to be a herd of antelope, thousands strong. Today in the desert grasslands between Socorro and the VLA, commuters still occasionally spot small herds of antelope, as well as plenty of jack rabbits, hawks, and an occasional coyote or soaring eagle. But, for the most part, this is now cattle country. In fact, shortly after the buses turn off Route 60 toward the VLA offices, they cross a cattle guard. For the next several miles the road crosses open range, where cattle have the right of way and vehicles must yield.

Arriving at the VLA

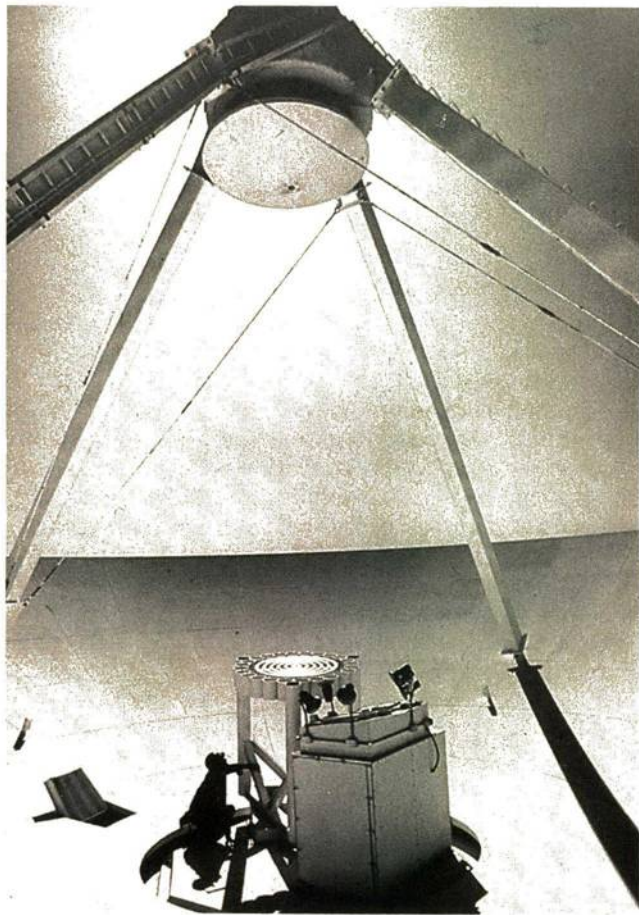
The cluster of buildings at the center of the array appears to be close by, but this is just an illusion created by the vastness of the plains; the turnoff is actually four miles from the parking lot. The VLA offices are confined to one square mile of land, which was purchased outright by the National Radio Astronomy Observatory (NRAO), a national organization that develops, maintains, and operates radio telescopes for the astronomical community. The arms of the array stretch along strips of ranch land leased from local ranchers.

The buses drop off scientific and clerical staff at the Control Building and technicians at the Electronics Building. Flanking the Control Building are the Visiting Scientist Quarters, which include the cafeteria, the meeting room, and the Science Library Office Building — abbreviated SLOB — a set of prefabricated structures where the astronomers' offices are located. A short walk from these buildings, the Electronics Building and warehouse are dwarfed by the neighboring Antenna Building, a giant hangar just big enough for a 25-meter parabolic antenna. Twenty-eight antennas were built for the twenty-seven-dish array, so one is always in the Antenna Building for

maintenance or repair.

Synchronized in their movement, the antennas of the array simulate a single, giant radio dish. With a technique called aperture synthesis, signals collected by the individual antennas are processed by computer to produce an image with the same resolution as an image obtained with a single telescope the diameter of the entire array.

Incoming signals can be directed into any of four receivers; in other words, the array can receive radio radiation at four different frequencies (or wavelengths): 1.3 centimeters (cm), 2 cm, 6 cm, and 18 to 21 cm. With a single computer command the telescope operator can shift the array from one to another of its four basic wavelengths. The antennas are currently being equipped with receivers to handle wavelengths of 91 cm. In addition, the National Aeronautics and Space Administration is funding x-band receivers, which, at 3.7 cm, will allow the array to receive signals from Voyager 2 during its Neptune encounter in August 1989.



Although a single telescope operator seated at a computer console controls the array, the observatory requires

Above: Inside the bowl of each antenna are feeds for the different wavelengths the VLA can receive. The 6-cm, 2-cm, and 1.3-cm feeds are on the box in the foreground, while the flattop object on three legs is for the 18- to 21-cm feed. The secondary mirror at top can tilt and the feed platform can rotate, routing the incoming signals into whichever feed is needed. NRAO/AUI photo.

Above, right: Moving a 200-ton antenna is a tricky and time-consuming process. Specially constructed "transporters" hydraulically lift an antenna, transport it along double lines of railroad track to its destination, and then carefully lower it onto a set of three pylons. Photo by Robert Burnham.

extensive support facilities. In fact, the VLA is practically a village in itself: it runs its own cafeteria and housing units, provides its own fire department and ambulance service, and maintains and services its own vehicles. The VLA must conform to state regulations concerning water, sewage, and so forth, exactly as if it were a village.

But the VLA is a national facility operated by NRAO, which in turn is managed for the National Science Foundation (NSF) by Associated Universities Inc., a nonprofit corporation that also operates Brookhaven National Laboratory in New York. NRAO allocates its NSF funding among three sites; the VLA receives about one-third of the total, or about \$6.5 million each year, which it manages autonomously.

The staff and users of the VLA form an international community, made up of an Australian director, radio astronomer Ron Ekers; and American, Dutch, British, French, Canadian, Italian, Spanish, Indian, and other radio astronomers who work there on staff or as visitors. As Ekers



points out, the international character of the VLA is "more than a reflection of the variety of the radio astronomy community. It's partly because this area of astronomy developed largely in Australia, the United Kingdom, and Holland, so the candidate pool is not primarily American."

The VLA maintains close ties with NRAO headquarters in Charlottesville, Virginia. Staff members travel between the Southeast and the Southwest in what seems like a constant stream, although Ekers says he'd like to see more interchange. "If you have separate sites that need to work together, the best thing you can do is move your staff around for significant periods of time," he explains. These visits are supplemented by teleconferences that take place nearly every day.

The Early Days

The VLA cost \$78.6 million to build — and it was completed on schedule and within budget. Construction began at the site in 1974, and by 1977 astronomers obtained the first scientific results with just six antennas. The array was completed and dedicated in 1981. Dave Heesch, NRAO director during the development and construction of the VLA, recalls that the VLA was “far and away the biggest ground-based astronomical project that had ever been.”

Bob Hjellming, a VLA astronomer who joined NRAO in 1968, was involved in the first scheduled scientific program. He and his colleagues used the array to observe stars, particularly x-ray stars and active binaries. He recalls the frustration of some of this early stellar work: “We observed a lot of stars and got negative results because we were using so few antennas. Later, when more antennas were available, other astronomers made the discoveries and published the papers.”

It was Hjellming who, along with colleague Campbell Wade, first realized that the VLA would be able to observe stars, even though it hadn't been designed for that purpose. “I said thirty supergiants would be visible at worst and at best as many as one million stars,” Hjellming remembers. Today stellar observations make up one-third of all the observations conducted with the VLA.

Jon Spargo, an NRAO employee for twenty years, was the first telescope operator at the site. When he arrived in 1975, he quickly became involved in building the antennas. Then he turned his attention to computers. “As the interface between the observer and the array,” he says, “the telescope operators had to be able to understand the computers.” Spargo helped design and install the com-

How to Move a Dish — Carefully

There are two ways to become famous at the Very Large Array: one is making a great astronomical discovery, the other is capsizing a telescope. The former has happened several times, but the latter, luckily, hasn't happened yet. Bill Del Giudice, head of the Engineering and Services Division, says, “We always remember that if we were to capsize one of the dishes, it would probably kill someone.”

Over seven hundred antenna moves have taken place since the VLA began operating in 1977. The antennas are moved for two reasons: to change the configuration of the array and to bring dishes into the Antenna Building for maintenance or repair.

The array is reconfigured four times a year so it can better observe different types of radio sources. Each of the four standard configurations is best suited for a certain type of observation; at its most extended, the array can map small, intense radio sources at high resolution, and at its most compact, when the antennas stretch only about one-third of a mile along the arms, the array can map much larger and fainter sources but at a lower resolution.

The system adopted for moving these huge antennas comes straight out of the nineteenth century. Double lines of railroad track run down each of the array's arms. At measured intervals there are short stretches of double rail that run perpendicular to the main tracks. Each of these side lines ends at a set of concrete pylons, on which the antennas rest.

Two specially constructed vehicles, called transporters, roll along the double rows of track. Swiveling bogies allow the vehicles to make 90-degree turns: the transporter rolls up to an intersection, stops, hoists itself up on feet, turns the bogies 90°, lowers itself, and rolls off in the new direction.

To move an antenna from one position to another, a transporter rolls under the dish, lifts it hydraulically, carries it to its destination, and sets it down gently on the pylons. How long does a move



Photo by Robert Burnham

take? Nowadays Del Giudice's staff can pick up an antenna in one hour. The transporter rolls the dish to its new location at a speed of 4 miles per hour, so the actual time in transit varies with the distance traveled and can be up to a few hours. Setting the antenna down takes another hour, and sometimes even longer. “The telescopes are a little fussy about being put down,” Del Giudice says.

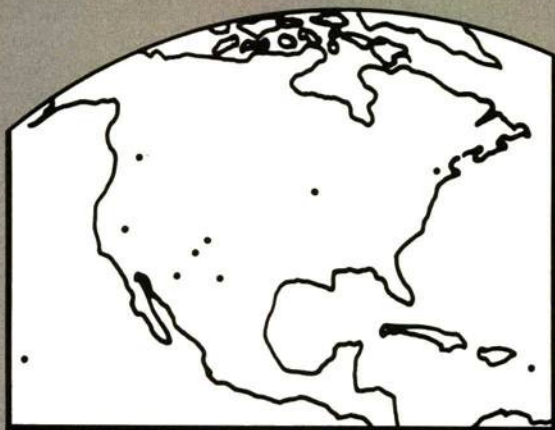
The operation is complicated by the narrow base and high center of gravity of the dishes. “They're very unstable,” Del Giudice says. Only once has a derailment occurred, and it was caused by abnormally cold temperatures. Del Giudice, who supervised the move, recalls that the morning was so cold “a rail cracked and broke, and the transporter dropped about four inches. It wasn't a serious problem, but it took us the rest of the day to jack the transporter back up and get it back on the rail.”

Nowadays a different problem slows down the moves: deteriorating railroad ties. Although the VLA is less than ten years old, some of the railroad track and ties predate World War I. Del Giudice explains, “When we built the place, we went to government installations and got surplus used ties and rails. This saved taxpayers a large amount of money.”

Now, however, the ties are deteriorating, and the VLA has neither the funds nor the manpower to replace the ties immediately. Instead, defective ties will be replaced gradually over the next several years. In the meantime, colored markers identify bad ties. “When the people transporting a telescope see several of these in a row, they slow down to less than 1 mile per hour,” Del Giudice says.

— Lys Ann Shore

One Good Idea Leads to Two Others



The Very Large Array has served as a model for two major new developments in radio astronomy: the Very Long Baseline Array (VLBA) and the Millimeter Array. Both are projects of the National Radio Astronomy Observatory (NRAO), which operates the VLA.

The VLBA will consist of ten dedicated, automated antennas — each identical to those of the VLA — distributed from Hawaii to the Virgin Islands. The first of the dishes to be built is located in Pie Town, New Mexico, about twenty-five miles northwest of the VLA site; the other planned sites are shown above. The VLBA's antennas will independently observe the same target at the same times, just as the antennas of the VLA do, but because it's spread out over such a large area, the VLBA will achieve the resolution of a single radio telescope 5,000 miles in diameter.

The necessary data processing will be carried out at a central computer facility in Socorro, New Mexico. The facility will be part of a new building that houses both the VLA and VLBA headquarters, the Center for Radio Astronomy Imaging, on the campus of New Mexico Institute of Mining and Technology. The building is expected to be ready early in 1988.

Meanwhile, VLA astronomer Frazer Owen is coordinating another NRAO project. The proposed Millimeter Array will observe radio sources at millimeter wavelengths with much greater resolution than a single antenna could provide. Owen views the new millimeter project as a logical extension of the techniques used by the VLA and VLBA. "It would be an array like the VLA, with a similar number of dishes, although the dishes would be clumped together more." And like the VLA, the Millimeter Array would be a powerful and adaptable instrument. The design is still being debated by a national study group.

Owen notes that "development of the Millimeter Array is drawing heavily on the expertise and experience of the VLA." With luck, the project could be operating sometime in the 1990s.

— Lys Ann Shore

puter console in the control room and eventually became supervisor of computer operations, his current position. Of the VLA's construction, Spargo says, "there's a lot of my sweat in this place. It's my instrument. When we held the dedication, in spite of all the verbose speeches by politicians, there were about a hundred of us who stood there, looked around at the array, and said to ourselves, 'Look what we built!'"

A Productive Scientific Instrument

The staff is proud of the VLA's enormous productivity. For example, Spargo claims that "the VLA produces more raw data than any other scientific instrument on the face of the Earth, be it a particle accelerator or whatever. And the VLA does this consistently, reliably, and at great speed, in spite of being underbudgeted and undercomputed."

There are several reasons for the VLA's great scientific productivity. One is the nearly weather-proof and light-proof nature of radio astronomy. VLA operations continue day and night, seven days a week throughout the year, with the exception of a few holidays. Ekers points out that the amount of usable time at a major optical telescope is about one-fifth of that at the VLA. In 1985 the array was "on the air" for 6,693 hours, which is about 70 percent of the total time available. Another 20 percent goes into maintenance, calibration, and related activities. "We're actually doing *something* about 94 percent of the time," Ekers says.

The VLA continues to operate even though bitter weather sometimes sweeps the plains. The wind is almost always blowing across the plains of San Agustin, and summer thunderstorms and winter snowstorms aren't unusual. Though they may be wind-buffed, gleaming with rain, or standing in snow as white as their high-reflectance coatings, the antennas keep turning. They were designed to operate in winds up to 40 miles per hour; if the wind blows harder, the antennas automatically switch to their "stow" position — that is, they point straight up. In this aerodynamically safe position the dishes can survive gales up to 125 miles per hour. (Winds of 90 miles per hour have been recorded at the site.)

The dishes were designed to last twenty years, but as Bill Del Giudice, head of the Engineering and Services Division, points out, "None of the antenna dishes has begun to wear out yet, and some at NRAO's operation in Green Bank, West Virginia, are thirty years old already."

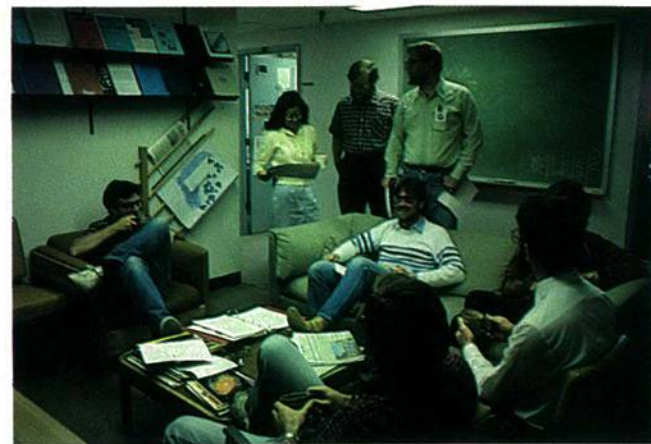
Another factor in the VLA's scientific productivity is the array's ability to take "snapshots" — short-exposure radio pictures — a capability for which the VLA is uniquely well-suited. The use of snapshots has been much greater than planned, according to Dave Heeschen, because the technique turned out to be much more effective than expected. When you're visiting the VLA, if you notice every time you look out the window that the antennas have shifted, it's a safe bet someone's observing program calls for a series of snapshots.

Antenna Problems and Solutions

Observations with the VLA continue as usual even when one or more of the dishes are out of commission. There are a number of reasons an antenna may be out of service. For example, four times a year the array is reconfigured — the VLA's four standard configurations allow it to observe a wide variety of radio sources — and, during the few weeks this takes to complete, between fifteen and twenty-four antennas must be moved. (The logis-

tics of moving an antenna are described in "How to Move a Dish — Carefully" on page 17.) Or one of the power cables that link the array may break, causing all the antennas beyond the break to blink out. This problem occurs fairly frequently nowadays, because the high-molecular-weight polyethylene the cables are constructed from is aging.

Del Giudice explains that when the VLA was built ten years ago, this substance was relatively new and highly recommended. Later, however, a study revealed that the substance has a comparatively high failure rate. "In November 1985 we began to experience these failures, although not as many as the study predicted," he says. "Nonetheless, it affects our operations. Typically what happens is that the failures occur along the arms of the array —because those cables stretch 13 miles — so we lose a few or several telescopes until the bad piece of cable can be replaced." The cable is being replaced grad-



scientist offices, congregating in the lounges, and most of all hunched over computer terminals in the "AIPS Cage." This room contains the Astronomical Image Processing System, the computer system that helps astronomers interpret their observational data. On Friday evenings you'll find them eating Mexican food at the Eagle Guest Ranch in Datil. What you're not likely to see is anyone observing, because there's very little for an astronomer to do while his or her observations are taking place.

Aileen O'Donoghue, an astrophysics graduate student at New Mexico Tech in Socorro and a junior research associate at NRAO, is using the VLA to study wide-angle tail radio sources in galaxy clusters. She describes a typical observing session this way: "There's a program on the DEC computer called 'Observe.' You go in and schedule your observation: you set it up and then check it, check it, check it. You hand a copy to the telescope operator, and then you walk away. You could stay and watch the

ually through a program that will take about three years.

This problem illustrates one of the chief conundrums facing the designers of a large-scale, user-oriented instrument like the VLA: do you use well-studied and long-tested technology, knowing it may be outdated even before the instrument is built, or do you specify state-of-the-art equipment, even at the risk of discovering problems later? Although the original designers decided to "stick with what was known to be safe," according to Heeschen, many of these safe choices were changed to riskier options by the time the VLA was completed.

On the other hand, in the decade between the initial design and the beginning of construction some choices that had been rejected as chancy came to be regarded as safe. Probably the best example of this is the VLA's waveguide system of signal distribution. Signals collected by the antennas travel to the central computer through buried tubes, called wave guides. The original design called for coaxial cable but, says Heeschen, "by 1972 we felt we could dump the coaxial cable design and go to a waveguide design. I think this was the most dramatic change in the design." But the state of the art changes constantly and, Heeschen muses, "If we were doing it today, fiber optics might be the way to go."

VLA Research

The VLA receives about six hundred observing proposals each year; of these, about three-quarters are granted at least some of the time requested. During any one week, from five to twenty-five visiting astronomers may be present at the site. You'll see them working in the visiting

fluxes coming in and see whether you're looking at something or nothing, but it's not necessary. One time, though, I was observing from 3 to 6 a.m., and I stayed in the control room talking to the telescope operator, drinking coffee, and watching the Sun come up and the antennas gradually appear out of the gloom."

Farhad Yusef-Zadeh, now a postdoctoral fellow at Goddard Space Flight Center in Greenbelt, Maryland, was another graduate student whose dissertation was based on VLA observations of the galactic center. Unlike most, however, Yusef-Zadeh and his collaborators, Mark Morris and Don Chance, experienced the thrill of making an important discovery in the course of their research: they detected gaseous filaments at the center of the Milky Way that cross the galactic plane almost perpendicularly. Yusef-Zadeh recalls that the 1983 observations were made at both 6- and 20-cm wavelengths. "When you find something odd, you always think it might be an artifact," he explains, "but if you see it at two different wavelengths, you can be pretty sure it's real."

It was late on a Saturday night, and Yusef-Zadeh and Chance were working on two different computers. "I was working on the 20-cm data, while Chance was working

Above, left: This station is the control center for the entire array. Telescope operators work in shifts to keep the array running around the clock.

Right: Astronomers take advantage of coffee breaks to discuss the latest astronomical developments. Photos by Robert Burnham.



on the 6-cm data. He left, so I had maps on both computer screens. We were working to get rid of what we thought was an artifact on the 6-cm map. I made a map of the 20-cm data and compared the two, and I saw that both showed the same structure. The 20-cm data showed the forest, the 6-cm data showed the trees."

Yusef-Zadeh, like many astronomers, believes strongly in being present when his observations are taking place. "Scientifically, it's better to be present so you can make decisions quickly if necessary. If you're not there, you lose that feeling of excitement and suspense. That's why I come."

About one-third of VLA observations, however, are performed for absentee observers by one of several staff data analysts. Ekers notes that "there's a great deal of interest in absentee observing. I had thought the percentage might go as high as 50 percent."

Staff astronomer Pat Crane points out that even if observers are present, they won't see their data in "real time." He added: "Before 1982 it was possible, but then we doubled the data rate; so now the observer sees data two to five hours after it was taken — not soon enough to allow you to do much in the way of making changes or adjustments." The pressure on the central computers caused by this high data rate has been somewhat alleviated by new hardware installed early in 1987.

Patrick Palmer of the University of Chicago is one observer who prefers being on the spot so much that for the last six years he has spent one-third to one-half of his time at the VLA, either observing or reducing data. Palmer first visited the VLA for six months in 1980, observing radiation from ammonia molecules associated with regions of star formation as well as familiarizing himself with the operation of the array.

Part of his attraction to the VLA is the site itself. "Here I can escape most phone calls," Palmer says. "The isolation is very valuable, but I also like the setting — sunrises and sunsets, for example. The skies are tremendous and always changing — and there's also the silence of the desert." Palmer's specialty is emission and absorption features in astronomical spectra; he and his collaborators used the VLA to observe the molecular and continuum emissions of Comet Halley in the radio region of the spectrum.

While spectral-line studies are one of the areas for which the VLA was designed, observing solar system objects "is not one of the things the array can easily do," Palmer says. The procedure is so delicate that Palmer's collaborators "are pushing me to write all this down in case I get run over by a truck," he adds. Processing the Halley data proved equally tricky because the comet was such a weak source. "It takes up to three hours to edit the data from a good observation of Halley," Palmer says, "but I have one from January 6, 1986, that I still haven't finished with."

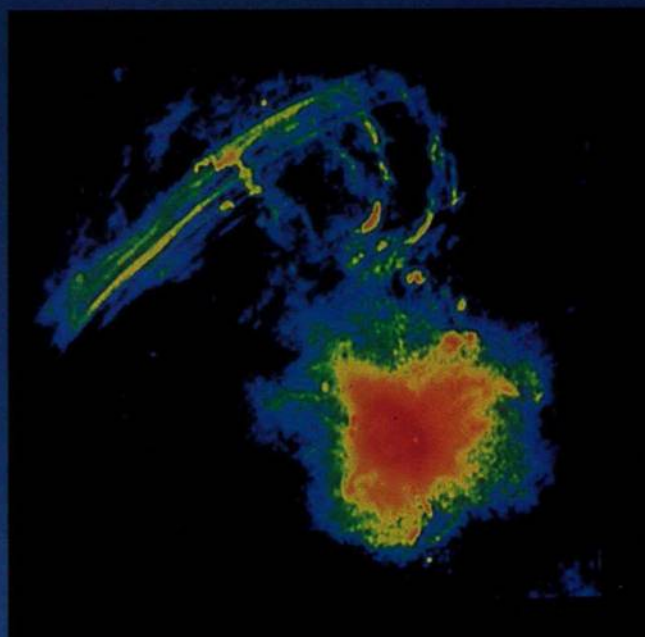
The Computer Bottleneck

When visiting the site, Palmer finds himself working at all hours. His explanation for this is simple: "In radio astronomy you can work twenty-four hours a day, so you do." But another reason the halls of the VLA are likely to be as crowded on a Saturday night as on a weekday afternoon has to do with computer overcrowding. In theory, fewer people should be using the AIPS comput-

ers late at night, so the machines should be less crowded, but often there is a crowd of astronomers trying to take advantage of the supposedly uncrowded conditions.

Astronomer Tim Cornwell, whose work at the VLA involves developing algorithms for image processing, describes AIPS as a set of programs giving the radio astronomy community "a common framework that we all live in." Like a toolbox, it contains an assortment of items that is constantly growing — in all, AIPS may contain as many as 500,000 lines of computer code. The system does for a radio observation what a bath of developer does for a photographic plate: it "develops" the data into a radio picture, or map, of a specific source or region. Because AIPS has grown according to the needs of the moment, the system can be complicated to use. Cornwell notes that "one thing we're interested in now is taking out some of the magic and making procedures more robust and bulletproof."

But this will only solve one problem. To relieve the



Above: High-resolution radio observations made with the VLA first revealed the presence of filamentary structures at the galactic center. In this false-color image obtained by Farhad Yusef-Zadeh, Mark Morris, and Don Chance, the narrow radio filaments appear at the upper left and are unbroken, parallel to one another, and perpendicular to the galactic plane. NRAO/AUI image.

Left: Each 25-meter-wide antenna is a powerful radio telescope in its own right, but the unique capabilities of the VLA come from combining the signals of all twenty-seven antennas. Photo by Robert Burnham.

computer congestion and set the facility on track for the future, the VLA has undertaken a "supercomputer initiative," and Ekers is optimistic the project will succeed. Cornwell says that "the supercomputer, if it comes, will really let this institution run at full tilt, which it hasn't been able to do before."

Meanwhile, computer frustration is part of life. Spargo, supervisor of computer operations, estimates that if all the computing power now at the VLA were added up, it

would equal about one-half of a supercomputer. "But if you look at the actual computing power used because of the way we have to fit all the systems together, you're talking about only one-tenth of a supercomputer," he says.

Although the Astronomical Image Processing System has been developed at NRAO, astronomers at many institutions have access to all the AIPS software. Nonetheless, most users prefer to do their "AIPS-ing" on site, where they have access to the necessary image-processing hardware, don't have to pay for computer time, and can call on the expertise of NRAO staff.

The Future of the VLA

Like many of the VLA staff and visitors, astronomer Jacqueline Van Gorkom enjoys hiking in the mountains that surround the plains of San Agustin. Surveying the array from a nearby ridge, she finds it "a strange contradiction to have this really busy telescope operation in the middle of this wide-open countryside, especially when



Above: An NRAO computer programmer tests one of the color monitors. The radio signals received by the VLA are computer-assembled into false-color images. NRAO/AUI photo.

Below: The dishes of the VLA stretch majestically across the plains of San Agustin. Photo by Robert Burnham.

you see those tiny buildings and think of people running around down there trying to finish their work." By mid-1988, however, there will only be half as many people "running around" the VLA site. That's when the new Center for Radio Astronomy Imaging (CRAI) is scheduled to be completed in Socorro, and many of the VLA staff will be relocated there.

Located on the campus of New Mexico Institute of Mining and Technology, the CRAI will house the offices of both the VLA and the Very Long Baseline Array (VLBA). The VLBA will consist of ten antennas spread from Hawaii to the Virgin Islands and will offer much greater resolution than even the VLA does. (For details on this new NRAO project see "One Good Idea Leads to Two Others" on page 18.) According to Ekers, scientific and clerical staff will move to the new offices, while staff directly involved with site activities (such as antenna engineering and so forth) will remain at the site. The reason for the move, he says, is "to best fit in with the VLBA. We want the benefit of having the two together."

The move will take place in two phases. Eventually in phase two the VLA will be operated entirely from Socorro. During phase one, which is expected to last from 1988 to 1991, observing will still take place at the site. According to staff scientist Frazer Owen, visiting observers will first spend a few days at the CRAI setting up their observations and then travel to the site for the period of their observing. Data would be calibrated either on-site or in town, and the astronomers would then analyze their data with AIPS at the Socorro offices.

No one is sure exactly how the move will affect the scientific environment of the VLA. Absentee observing will likely increase, and most view that as unfortunate. As Ekers says, "If we make it possible to do everything easily from Socorro, then there would be very little difference between coming to Socorro and dialing in from your home institution. And I'm old-fashioned enough to believe that being in the presence of the telescope — the magnificent engineering of the telescope — provides something very special."

Owen acknowledges that "whenever you move an operation, there's a degree of risk. But we'll gain some things as well. We may be able to have an outstanding scientific environment if we do it right." For one thing, locating the observatory offices on a college campus will provide a closer link to the academic community. NRAO has long recognized the danger of losing the next generation of expertise because of a lack of contact with academic programs.

In the future fewer astronomers may have the opportunity to succumb to the magic sight of antennas marching across the high desert plains. Those who have stayed at the site, however, aren't likely to forget the experience. Yusef-Zadeh recalls one dawn when he looked out at the dishes, which had their backs turned to him, "and it was as though they were extraterrestrials standing there. It's as if they're watching you, standing up and guarding the control room."

Lys Ann Shore is a writer and editor living in Socorro, New Mexico. Her most recent contribution to ASTRONOMY was "IUE: Nine Years of Astronomy," published in the April 1987 issue.



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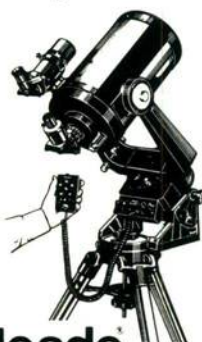
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ASTRONOMY Forum

How Dark Was the Night of the Boston Tea Party?

"Would you be able to find out what the Moon phase was on December 16, 1773?"

With this question I had the feeling Professor Joseph Konhauser, mathematician and puzzle connoisseur, was setting me up for one of his puzzles.

"That's when the Boston Tea Party took place," Joe added.

"In 1973 a block of four stamps commemorating the Boston Tea Party was issued," he explained. "On the upper right stamp of this block the Moon was shown as a crescent. All I want to know," he continued, "is if the phase depicted was the actual phase or the artist's conception."

So I got to work. Out came the

200 years by the length of the synodic cycle of the Moon, I got 2,473.7492 as my answer. I felt this number could be safely rounded off to 2,473 and 3/4 cycles, which represents the number of synodic cycles between the two dates.

The December 1973 issue of *ASTRONOMY* placed the First Quarter Moon on December 3, the Full Moon on December 10, and the Third Quarter on December 16.

If the division of the number of



Joe knew I had a large reference library. Maybe there would be some sort of chart depicting lunar phases and their times of occurrence. It wasn't that easy. I checked through my books that night and found there wasn't any reference that went back that far. While the phase of the Moon can be interpolated from schedules of lunar and solar eclipse dates, I didn't have those on hand either.

The next day I asked Joe why he wanted to know this obscure piece of information.

pocket calculator. Out came the reference books. The length of Earth's sidereal year is 365.25636 days. Multiplying the sidereal year by 200 years gives the actual number of days separating December 16, 1973, from December 16, 1773. (This allows for leap year intervals automatically.) The number of days separating the two dates worked out to be 73,051.272. The assigned value of a lunar synodic month (the time between two successive New Moons) is 29.53059 days. When I divided the number of days in

elapsed days by the length of the lunar phase month had come out without any remainder, the Moon two hundred years ago would have been in the same phase as it was in 1973. Because December 16, 1973, was 3/4 of a cycle farther along than on the same date in 1773, the Moon would have been New and not visible in the night sky as the "Indians" dumped tea into Boston Harbor. This means the creator of the stamp exercised his artistic license and drew in a crescent Moon.

A friend worked out the answer by Julian Day numbers and came within a day or so of the answer I had determined. He cautioned that the period of the phase month may not be a nice cozy constant. This could sway the answer a day or more in a two hundred-year period.

An interesting astronomical puzzle, to say the least. And Joe's cherubic smile when I showed him the answer justified my efforts to solve it.

Sherman W. Schultz
St. Paul, MN

Supernova 1987A,
Halley's Comet,
the Galactic Center...

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extraordinary celestial
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NGC 300 is a magnificent Sc Galaxy in the Sculptor group. Most of the galaxy appears blue because of the high content of young, hot stars. A composite of three individually exposed plates, the photo shows the trail of an artificial satellite that crossed the field during the red exposure.



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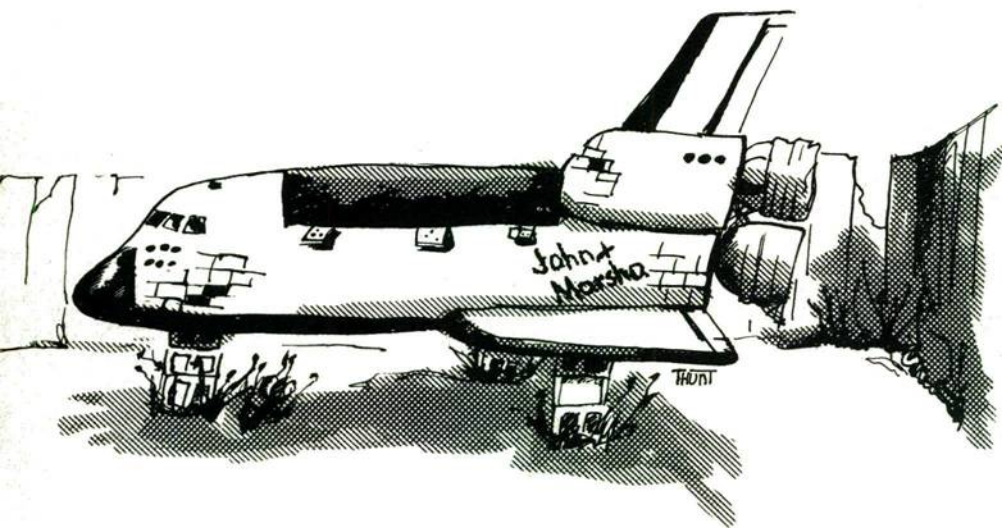
Winning the Battle of the Space Budget

The battle of the budget has been raging at NASA for over a decade. Despite the exploding number of groups on the pro-space side — the Planetary Society, Delta Vee, Space-watch, the Citizens of Space Political Action Committee, and the new National Space Society — NASA remains on a bread and water diet.

The pro-space movement should

pennies" is more like it. Unless you have several hundred pro-space friends who have several million dollars to spare (or several million pro-space friends with several hundred to spare), money isn't a strong resource.

We are committed to our goals, however. This doesn't cost anything and it doesn't take huge numbers of people. The pro-space movement must



have a lot of clout. The movement is widespread and growing, and its members can vote and have the right to petition the government, the basic sources of clout in the American political system.

So why is the space program slowly dying of malnutrition while the pro-space movement screams for more funding? Just recently the Planetary Society failed in its campaign to keep the Mars Observer launch in 1990. Rather than stamp our feet or scratch our heads at frustrating situations like this, we should try to understand why the pro-space movement currently lacks the political clout necessary to rejuvenate the space program and then work to change the situation.

The clout a group has depends on many variables, but the six most important political resources are size, money, commitment to goals, knowledge of the political system, political standing, and organization.

The pro-space movement is relatively small, though there are uncounted millions of pro-space sympathizers (the elusive "silent majority"). Our size could be a strong political resource, but because the thousands of pro-space supporters belong to different groups, the political advantages of our size are minimized.

From what I've heard from most groups, the pro-space movement isn't exactly "rolling in dough"; "pinching

be strong in this area, right? Wrong. Although a number of people are strongly committed to their goals and are willing to work hard to achieve them, many people who support a stronger space program and increased space exploration are "armchair lobbyists." They think their help won't accomplish anything, so they just sit back and say, "Something's bound to happen." And lo and behold, something does happen — NASA's budget is reduced even more!

We must change the attitudes and behavior of a lot of people, which isn't an easy task. It does not, however, take that much effort to mail a letter or cast a vote, and with a little motivation and organization many nonactive space enthusiasts could be persuaded to actively support the space program.

You'd think a lot of pro-space people would know the political system well enough to make good use of it. But in reality probably only a handful of pro-space people know the system. With the exception of a few pro-space politicians and an occasional experienced pro-spacer, the movement is still pretty much at the grassroots level.

While learning the system is difficult, it is not impossible, though it will take a lot of time and work. There are politicians who know the system and support space exploration, and many other pro-spacers are becoming experienced lobbyists, but they can't do the

job alone.

And there must be some politicians who favor an increased space budget. Pro-space legislation has been presented in the Senate and the House, but the opposition is rather strong and support from constituents relatively weak. We cannot expect or hope our "friendly" politicians will pull the full weight of the pro-space movement. They desperately need our support.

Gaining political standing isn't easy. The pro-space movement needs a lot of time before it can have a major effect on elections, but if we support and cooperate with the pro-space politicians already in office, this political resource could become quite valuable.

We're a little weak in other resources, but we're organized, aren't we? Actually, the pro-space movement is anything but organized. The movement is made up of myriad professional, research, and educational groups as well as grassroots organizations, science fiction fan clubs, and other miscellaneous groups. Space exploration is nondenominational, cutting across all political, sociological, and educational boundaries, but this diversity of support is not without problems.

There are over a hundred pro-space groups scattered around the country, each working on its own to advance space exploration. There is some cooperation and communication among a few groups, but many aren't even aware others exist, and what's worse is that many don't seem to care. At the moment, organization is not one of the pro-space movement's prouder achievements.

The effectiveness of pro-space groups is weakened because the thousands and thousands of members are spread out among a hundred or so groups. However, just as a hundred different individuals are more effective if they cooperate and all do the same thing at the same time, a hundred groups cooperating with one another are much more powerful than a hundred groups all doing their own thing. The recent merger of the LS Society and the National Space Institute is a step in the right direction.

Organization is the pro-space movement's most valuable and most readily accessible political resource. Convincing the majority of groups in the pro-space movement that organization is the key to our success is all that's needed for us to succeed. If we aren't organized, the pro-space movement simply will not get anywhere. We must get organized.

So, what's the problem? Organization seems like a fairly simple task. After all, we're all working for the same goal.

But each group wants to retain its

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individual identity and power. While this is understandable, most groups fail to realize just how much potential power they'd have at their fingertips if they just learned to cooperate with other groups. If everyone who supports space exploration stood up together and demanded more funding for NASA, NASA would get more funding. The pro-space movement could be that powerful.

There are many ways to bind the pro-space movement together. Loose confederations of different organizations are already being created by some pro-space groups, and others are forming "phone trees" among members to increase communication and coordinate activities.

The formation of a communication network where groups could exchange information and ideas would be an important step towards unity. A single newsletter could be issued to all subscribing pro-space groups and

individuals. The newsletter would describe events and campaigns each group is undertaking and provide a forum for debate and cooperation. Joint activities such as letter writing campaigns and even marches and demonstrations could be planned. Each group could participate and contribute while maintaining control over its own activities. Rather than being swallowed up by one monster organization, each independent group would make an individual contribution to the common cause.

The only way to insure a strong space program is for everyone who believes in the importance of space exploration to speak out and say in one loud, unified voice, "We want a strong space program!" The power, the desire, and the ability are there. Let's begin working together to save our space program before it's too late.

Martin Sickler
San Diego, CA

Observing an Amateur Astronomer: His Wife's View

Standing in the park with my husband can be so romantic, especially when the sky is lit with delicate stars. But with twenty amateur astronomers and their telescopes crowded around us, getting romantic can be difficult.

Jim and I have been married only twenty months; astronomy has become Jim's major hobby in the last eight months. He became interested in astronomy during the return of Halley's Comet, the same year we received a telescope as a combined birthday present. Since then his interest in astronomy has increased — alarmingly.

I'm lucky this interest developed after the wedding and not before, because I lived 125 miles away from Jim when we were dating, and arranging time together was occasionally difficult. I sometimes feel that if Halley's Comet had returned one or two years earlier, I'd still be single.

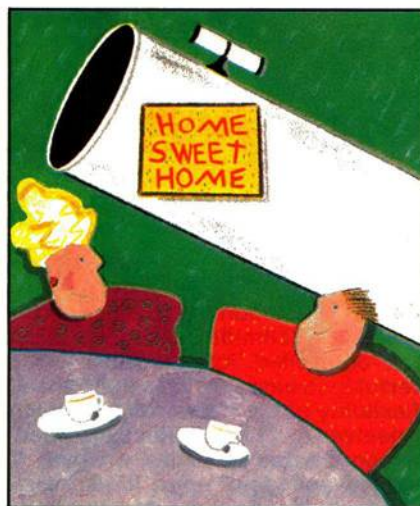
Originally Jim wanted to build a 10-inch telescope. He made various diagrams and double-checked his mathematics for accuracy. His plans changed, though, when we went to a star watch at a local park, where Jim had the chance to view through a 17.5-inch telescope. He was so excited his eyes sparkled. Soon he was dragging his tongue on the ground and panting every time he approached this large scope.

What could I do except suggest he get his own ready-made 17.5-inch telescope? So we ordered the telescope. He didn't mind having wasted hours perfecting the diagram for the 10-inch telescope — he was too elated about the 17.5-inch telescope.

Waiting for a telescope can be

exciting for any family. It's just like expecting a baby. (If he shows anywhere near that much excitement when I'm pregnant, I'll be elated.) My husband has been making plans galore. He's been looking into luggage racks for my car. You know, the ones that look like a gigantic hamburger to go! With this luggage rack we can pack up everything and zip to sky watches everywhere. Jim thinks the telescope should be kept in the dining room. I think he feels that if the telescope is kept in a building behind the house, it might get lonely.

Jim clearly has become obsessed with astronomy. Whenever we're out after dark, he constantly watches the sky. I can tell the sky is clear just by his "Oh, what a night!" Every day I get a personal forecast for that evening's viewing. (Every wife needs her own private meteorologist.)



When we drive around at night, Jim points out to me areas of the North Carolina countryside that are "deep sky country" — perfect for telescope viewing." Recently, along a highway near Asheville a number of streetlights lining the highway had been turned off. As a representative of astronomers everywhere, Jim wanted to write Asheville to thank the city for turning off the lights. (I think the lights were turned off for economic reasons instead of light pollution, but don't tell Jim.)

Sometimes his obsession goes too far. For instance, we were hunting for an educational coloring book for a nephew who is almost three years old, and Jim suggested a children's astronomy coloring book. His idea was good, but where would I find a box of crayons with only black (for the sky) and white (for the stars)?

As members of the Astronomy Book Club, we have an astronomy collection that's better than our local library's. Along with books on astronomy, deep-sky objects, and workbooks on observing, we have several books on building telescopes. Since we ordered the 17.5-inch telescope, the telescope-making books aren't getting much use. (If you're interested in building a scope, do I have a deal for you!)

Spouses of amateur astronomers should have a lonely hearts club or our own "Dear Abby." Jim is often gone several evenings a week — observing. I keep his picture handy to remind me of what he looks like. On weekends I occasionally accompany him on sky watches. After four hours I'm ready to return home, but he's just getting geared up for the evening. I'm looking for a shop that sells books that glow in the dark. If you know where they are sold, contact me immediately.

Recently we've been discussing a new home — not right away, but a couple of years down the road. For Jim the primary factor isn't the size, style, location, cost, or condition of the house. He wants to purchase a home in an area perfect for deep-sky observing. To locate an affordable home that fits his astronomical needs, we may end up living outside of civilization.

Being married to an amateur astronomer is never boring. Whether he's searching the Greek dictionary for the perfect name to give his new telescope or freezing until 1 a.m. hunting the Veil Nebula, he is definitely enjoying himself.

But lately he's been talking about a man in Charlotte who is the proud owner of a 29-inch telescope. To tell you the truth, I'm beginning to get a little nervous.

Rachel Critchley
Bessemer City, NC

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ASTRONOMY

In Focus

Space Art to Ruin Skies

Sir / Peter Ceravolo's "In the Glare of the New Moon" (Forum, May 1987) may be closer to reality than we fear. France is planning to launch a giant reflective satellite "work of art" in 1989 ("Eiffel Tower Space Art Criticized," AstroNews, July 1987).

The French seem to have forgotten the meaning of their own word *gauche*. Already a significant percentage of my astrophotos are blemished by satellite trails. How many of us have had to explain, "No, that's not a scratch. It's a satellite."

The first satellite with the sole purpose of lighting up the night sky annoys me more than the 200-watt stereo blaring next door.

Tom Dey
Springwater, NY

Sir / What effect will this outlandish space art scheme ("Eiffel Tower Space Art Criticized," AstroNews, July 1987) have on transparency? Will it be like another Full Moon circling every three to five hours, or will it merely be conveniently placed to make interesting pop art out of my carefully guided astrophotos?

Just when we were beginning to make the public understand what light pollution is, the French come along with plans that could possibly ruin the sky for three years! Many spider webs will collect on my 10-inch telescope over three years. And this extraterrestrial spectacle will be boring after three days.

Michael D. Batchelor
San Diego, CA

More Northern Spectacles!

Sir / Readers in the Northern Hemisphere are being ignored! Your magazine is blatantly catering to your readers in Madagascar, the Kerguelen

Islands, Australia, and New Zealand. The evidence for this favoritism is overwhelming: Comet Halley, Comet Wilson, supernova 1987A, as well as the recent lunar occultations of Jupiter and Antares.

I think you should arrange something spectacular for the Northern Hemisphere. Might I suggest a nova in Leo (1st-magnitude or better would be nice), a naked-eye equivalent of the Ring Nebula, or even a nice meteorite shower? No Cosmos satellites, though. The last one hit a lake and there just isn't any local market for whitefish that glow in the dark.

I would very much appreciate some honest attempts to bring more of the upcoming cosmic events above the horizon where your Northern Hemisphere readers can see them.

Richard Corbet
Calgary, Alberta, Canada

— *In a field like astronomy you have to take what the universe dishes out! The Northern Hemisphere does get some of the celestial treats. Comets West and Bennett out-spectacled Comets Halley and Wilson by a wide margin, Nova Cygni was 1st-magnitude, and what about the solar eclipse that crossed Alberta a few years ago?*

Seeing the Giotto Movie

Sir / Richard Berry mentions the movie made from the Giotto flyby frames and "hopes that sooner or later every ASTRONOMY reader will have a chance to see it" in "Halley in Heidelberg, Planets in Paris" (Forum, March 1987).

When and how will this movie be made available to us?

Gary L. Brown
Sandoval, IL

— *There are several ways our readers*

might eventually get to see the Giotto flyby movie. It might be incorporated into a television documentary on the scientific results from Comet Halley or presented in a remake or continuation of a series like "Cosmos" with Carl Sagan. It might also be included in a commercial 12-inch videodisc of space imagery. You can see the best composite image in the June 1987 issue in "Search for the Primitive" by Richard Berry.

Where Is Voyager 2 Heading?

Sir / "Star Trek Part One: The Adventure Begins" by David Darling (Stellar Frontiers, March 1987) provides a fascinating journey of the imagination, especially for those of us who like bedtime reading.

I am puzzled, though, because the article states that Voyager 2 is expected to pass within 0.2 parsec of Sirius. This is strange because when Voyager 2 encounters Neptune, the spacecraft is moving toward Sagittarius, which is in nearly the opposite direction of Sirius.

I can reconcile this in two ways. Neptune's gravity will deflect Voyager means 2's trajectory toward Sirius or Sirius will pass by the solar system and "catch up" with Voyager 2. However, neither of these solutions seems too reasonable.

Edward Earl
Salt Lake City, UT

— *Your first guess is correct. When Voyager 2 encounters Neptune, the spacecraft's trajectory will be sharply deflected by Neptune, according to Charles Kohlhase, manager of JPL's Voyager Mission Planning Office. With this change in direction Voyager 2 will encounter Sirius at a distance of 1 parsec in 250,000 years. Originally, the craft would have passed within 0.2 parsec of Sirius, but since the article*

was published, JPL has altered Voyager 2's trajectory to make the most of the Neptune encounter in 1989.

Scale of Quasar Maps

Sir / John Mood's "Star Hopping to a Quasar" (Gazer's Gazette, April 1987) inspired me to look for 3C 273. Only one thing was missing from the charts provided with the article — the scale. Can you tell me what the scale was?

John West
Bryan, TX

— Rather than draw each chart to a particular scale, we chose to present the important regions and star patterns necessary to star hop to 3C 273. A rough scale for all the charts can be derived from Chart 1, in which each block equals 15°. In Chart 2, 1° equals 7.5 millimeters; in Chart 3, 1° equals 5.5 centimeters; and in Chart 4, 1° equals approximately 3 millimeters.

It Should Be Greek to You

Sir / The European Space Agency mission around the Sun, Ulysses, described in "Voyage into the Third Dimension" by Gary L. Bennett (May 1987), should have been named Odysseus in honor of the "greatest explorer in Greek mythology" instead of Ulysses, which is the Latin version of Odysseus.

Harry Zantopoulos
North Canton, OH

Astronomy with a Permit

Sir / You may be interested to know that astronomy requires a permit at one place in Oklahoma. That's right — a permit!

My wife and I were camping in the Wichita Mountains Wildlife Refuge last April and we left the lights of the campground to set up our telescopes. A ranger showed up and asked if we had a permit. She also informed us that "anything not expressly permitted in the refuge is forbidden." The ranger was polite about this and told us we could continue without a permit "this time."

The incident is ironic especially because we're celebrating the two hundredth anniversary of the Constitution this year. Surely, even in Oklahoma, we do not need a permit to look at the stars.

Lee Paulsel
Fort Worth, TX

Arizona's Sun Times

Sir / Besides the well-known astronomical sights in Arizona that were highlighted in ASTRONOMY's 1987 Summer Travel Guide (June 1987), our

state offers something none of the other contiguous states can offer: Arizona does not observe daylight saving time.

The Sun rises and sets when it's supposed to instead of when Congress decrees!

S. W. Bieda, Jr.
Sierra Vista, AZ

Reawakening Your Childlike Curiosity

Sir / Sometimes I can't get motivated for a night of observing, and I'll use any excuse — a cloud, the weather, my neighbor's porch light — to avoid setting up my telescope. One night, as I was going through my list of excuses, I discovered a trick to motivate myself: I looked up and rediscovered that mag-

ical, familiar feeling. I was five years old again as I absorbed the glorious panorama of the stars above.

The stars of Pegasus and Andromeda lay above the northeastern horizon. The summer triangle hovered overhead. I remembered how I had taught myself the constellations and the names of the stars.

Reawakening that childlike curiosity and the wonder and awe of the universe rekindled the fire that led me to observe in the first place.

Nicholas Colangelo
Farmingdale, NY

Oops!

The distance to quasar PKS 2152-09 ("Quasarlike Activity Discovered in Fringes of Radio Galaxy," AstroNews, May 1987) is 153 megaparsecs.

Behind the Scenes

Getting the Whole Picture

Our space program is mired in contradiction and confusion. Just when we should be reaping the benefits of our twenty-nine-year investment in space, we find ourselves waiting another year for the first "test flight" of a slightly modified and considerably less capable Space Shuttle. Two great space missions, Galileo and the Space Telescope, quietly age as they wait for launch dates still possibly years away. Even the joint Air Force/CIA "spy in the sky" program sits in limbo.

How did we get into this mess?

Two recent books detail the gradual decay and sudden failure of the American space program. Joseph Trento's *Prescription for Disaster* (Crown, 1987) tells the tale of the dirty politics, interagency conflict, and personal ambition that resulted in an inevitable disaster — the Challenger explosion. Based on hours of interviews with every one of NASA's top administrators and dozens of NASA, White House, and Congressional insiders, the book portrays the rise of NASA in the time of Apollo, Nixon's stab-in-the-back budget cuts, the knockdown-dragout battle between the proponents of a commercial/scientific Shuttle and those of a military Shuttle, and the death of quality control.

William E. Burrows' *Deep Black* (Random House, 1986) tells of America's hidden space program, the top-secret "black" side of space. Vital to American security, optical and electronic spy satellites provide

American intelligence with realistic estimates of enemy strength. The costs of our "deep black" program long ago overran the "white" civilian space program; today it receives roughly twice NASA's total funding.

Although Eisenhower opposed placing the American space program in military hands, the U-2 incident and Cuban missile crisis showed the value of reconnaissance from space. Burrow's descriptions of 2-meter-aperture orbiting spy telescopes leave little doubt about where technology for the Space Telescope came from.

Taken together, these books paint a disturbing picture of our nation's role in space. Obsessed with secrecy, the military space program consumes vast resources to produce an "intelligence product" that our politicians, according to Burrows, would rather ignore, while the civilian space program now limps along underfunded and run by the same administrator, James C. Fletcher, who, according to Trento, failed to make the Shuttle work the first time.

If you're concerned about America's space program, these are books you *must* read.

Sincerely,



Richard Berry
Editor-in-Chief

Watching Earth Move with the Shadow Clock

by Bruce McClure

Once the sundial was mankind's clock. It occupied a place of honor in the courtyards of royalty and monasteries around the world. But today the venerable sundial is used as little more than an ornament in gardens and birdbaths.

You can, however, learn a lot about the workings of our solar system from a properly built sundial, as astronomers did in centuries past. Although its primary task is marking the passage of time, which the sundial does very well when correctly oriented, astronomers discovered that this precursor to the solar calendar and the mechanical clock was capable of much more complex measurements. Seasonal phenomena such as the solstices, equinoxes, and the apparent path of the Sun were first "read" by astronomers in the lengths, directions, and movements of shadows across the sundial.

The sundial and its close cousin, the armillary sphere, have also contributed much to our geographical literacy. Astronomers derived cartography and the concepts of latitude and longitude, as well as discerned the presence of the North and South poles, the Arctic and Antarctic circles, the equator, and the tropics of Cancer and Capricorn long before explorers actually visited these places.

The exact origin of the sundial is unknown. The Greek historian Herodotus, who lived in the fifth century B.C., traced the sundial to Babylon, which is not sur-

prising considering the Babylonians' devotion to watching the heavens. In fact, the legacy of Babylonian astronomy — the 18.6-year eclipse cycle of the Sun and Moon — would probably never have been discovered without the sundial.

The Early Sundial and the Solar Day

Archeoastronomers believe the earliest sundial consisted of nothing more than an upright stick, called a gnomon, sticking straight out of level ground. The shadow cast by the gnomon was less like the hour hand of a clock and more like a bench mark that indicated when morning, noon, and afternoon occurred. Nevertheless, as crude as this device might seem to us, possibly 10,000 years ago people used this type of sundial to determine noon with nearly to-the-minute precision.

How was such precision possible? The whole key to pinpointing solar noon, a sacred moment for those people who used sundials, was knowing when the Sun crossed the meridian, the great circle that runs across the celestial sphere connecting the north and south horizon points and passing through the zenith. But, to locate the meridian, finding true north (or in the Southern Hemisphere, true south) is essential.

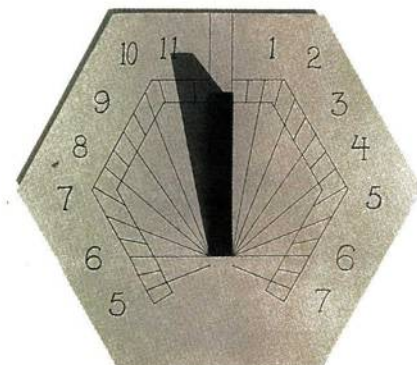
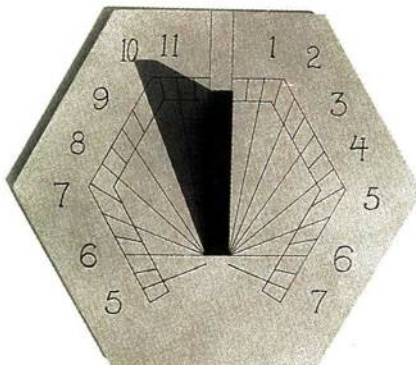
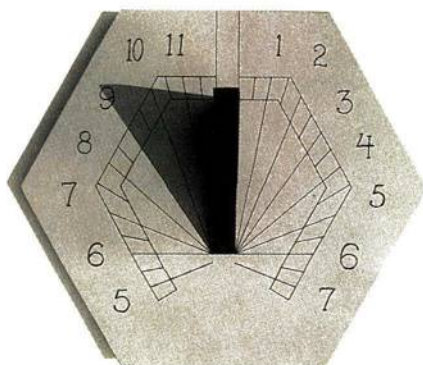
Since ancient times astronomers have known the Sun reaches its highest altitude at local noon. At that time the Sun lies on the meridian and a vertical gnomon casts its shortest shadow of the day. This

shadow points north in the Northern Hemisphere, south in the Southern Hemisphere.

Determining Noon

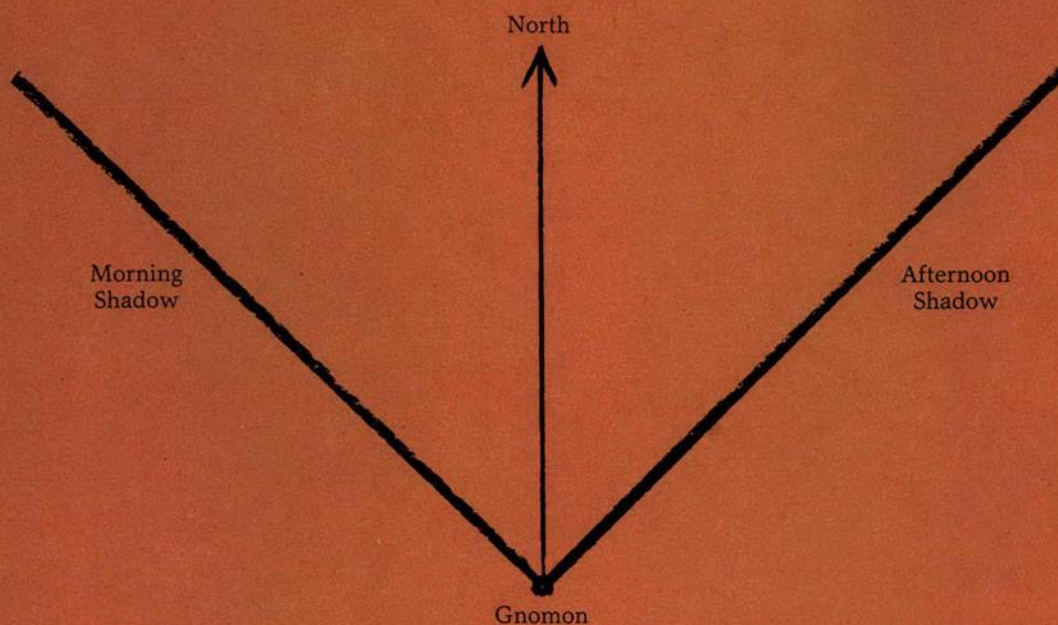
Finding true north or south is simple. All you need is a sunny day and a gnomon (a straight stick will do). First, mount a vertical gnomon on a level platform (use a carpenter's level to make sure the gnomon is plumb and the platform is level). About mid-morning, mark the length of the shadow made by the gnomon on the platform. In the afternoon, record the shadow's length when it is the same as the shadow you noted that morning. The line bisecting the angle defined by these two shadow lines points north in the Northern Hemisphere and south in the Southern Hemisphere. This line also marks noon.

This method, however, lacks the absolute precision the horologist of yesteryear would have expected. Because the Earth's axis is tilted 23.5° to the plane of Earth's orbit, the Sun's path across the sky gradually shifts in declination (its apparent location north or south of the celestial equator) as the Earth goes around the Sun. Thus, the shadow lengths cast by the gnomon at noon vary perceptibly, both on a daily and a seasonal basis (they're longer in winter and shorter in summer). Moreover, the Sun's rising and setting directions change throughout the year, so the direction of the gnomon's shadow also varies





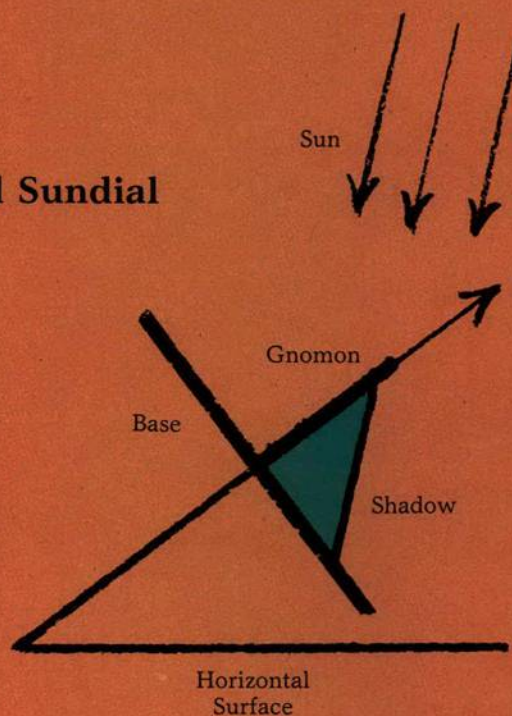
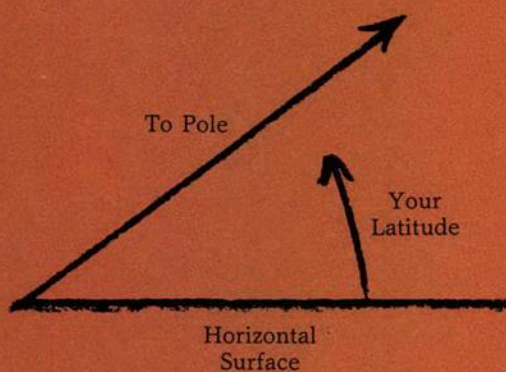
Finding True North with a Shadow



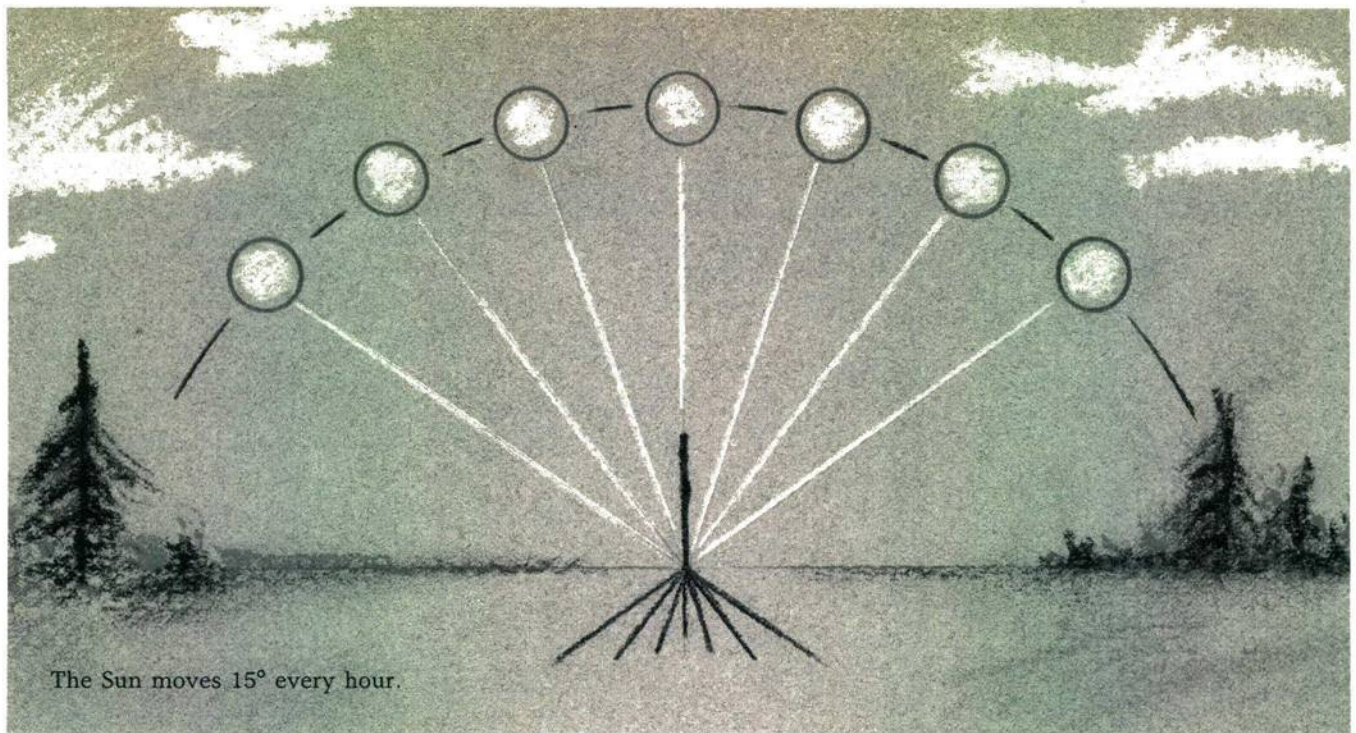
True north lies halfway between an afternoon and a morning shadow of equal length. The gnomon must stand exactly vertical, and the shadows must fall on a flat, horizontal surface.

The Equatorial Sundial

The gnomon points toward your celestial pole . . .



. . . and the base is perpendicular to the gnomon.



from day to day.

These variations in shadow length and direction meant that early sundials didn't equally measure the hours. For the ancients who tried to divide the day into equal increments of time, these small inaccuracies accumulated into more serious errors as the seasons progressed. Although astronomers knew that an accurate reading was least obtainable near the equinoxes (when the Sun was crossing the celestial equator) and most obtainable near the solstices (when the Sun reached its most northerly or southerly point), this didn't help standardize the hour. Sundials designed to counter this problem, such as those using a separate hour scale for each month, often were more complicated and cumbersome to use.

The Equatorial Sundial

Then, at an indeterminate point in history, some unsung genius discovered that orienting the gnomon parallel to the Earth's rotational axis standardized the hours, because this positioning was not affected by the Sun's declination.

Now, go back to your stick-in-the-

ground sundial. If you're located at the North or South Pole (90°), your gnomon will be vertical; if you're located at the equator (0°), your gnomon will be horizontal. At a location between the poles and the equator, your gnomon must be inclined by an amount equal to your latitude. For example, if you are located at 30.5° north latitude, the upper end of your gnomon should point 30.5° above the north horizon along your meridian. If you are located at -43.7° south latitude, your gnomon must point 43.7° above the south horizon along your meridian. In other words, the gnomon should point to the celestial pole of your hemisphere.

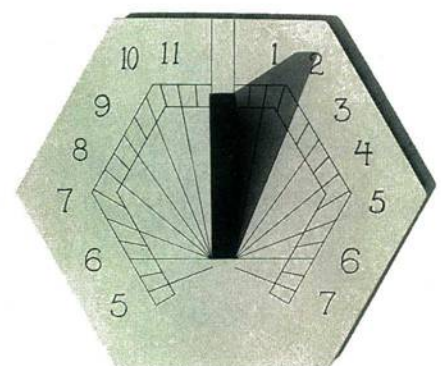
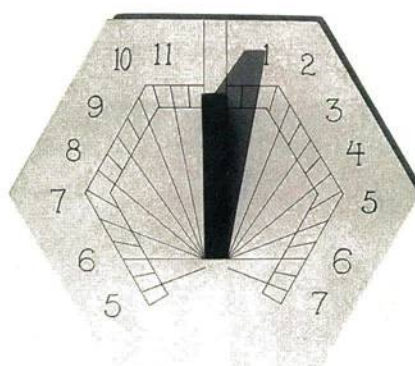
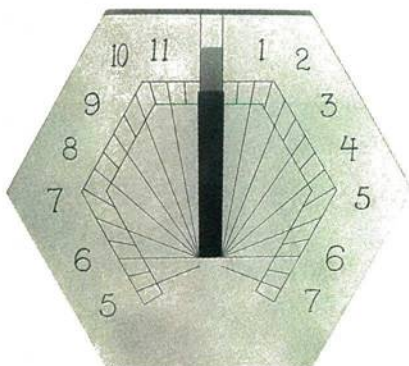
In addition to inclining the gnomon parallel to the Earth's axis, you should also set the base of the sundial parallel to the plane of the equator. This is done simply by orienting the base at right angles to the gnomon once the gnomon is aligned with the Earth's rotational axis. At the poles, then, the base would be horizontal; at the equator the base would be vertical.

With these design improvements you've suddenly leaped centuries ahead of the stick-in-the-ground sundial and discovered

the equatorial sundial. Whenever the Earth completes $1/24$ th of its daily rotation, the equatorial sundial directly measures one true solar hour, which is the duration of time accompanying each successive 15° westward shift in longitude of the Sun. All that's left to do is spacing your hour marks 15° apart on the dial. This scale of hours will work for the entire year.

Correctly oriented, the sundial is a geometric wonderwork that can open your eyes to the consequences of our planet's motion in space. The sundial aptly demonstrates the relationship between the hour and the Earth's 360° rotation in reference to the Sun, the cycle of the seasons, and the orbital motion of the Earth. If you have a sundial languishing in a forgotten flower bed, dust it off and calibrate it. Think about the cosmic "clockwork" behind its shadow play and rediscover its priceless heritage.

Bruce McClure is a part-time carpenter and farmer living in Winthrop, New York. McClure also writes newspaper articles and speaks at local schools about astronomy.





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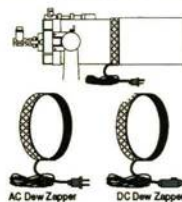
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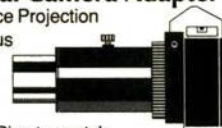
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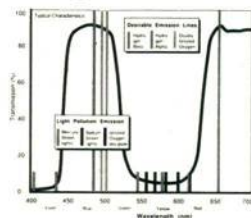
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Prospects for the March 1988 Total Solar Eclipse

by Jay Anderson

The Moon slowly eats away at the disk of the Sun, seeming to devour our star as our early ancestors once imagined. The process takes only an hour but feels much longer — waiting a lifetime has distorted your perception of time. Finally the last tiny sliver of the Sun's disk disappears. You now stand in the darkest part of the Moon's shadow: night has arrived in the middle of the day.

For the third time in the last five years the Moon's shadow is returning to Southeast Asia. Next March 17-18, the longest total solar eclipse in five years will occur for observers in a narrow strip that crosses portions of Indonesia and the Philippines as well as a large expanse of ocean. Picking the best location to witness this event takes quite a bit of research, but the rewards of a good location are well worth the effort.

Why an Eclipse Now?

A solar eclipse happens whenever the Moon passes directly between the Sun and Earth, causing at least part of the Moon's shadow to touch Earth. Every month at New Moon this condition is nearly met, though usually the Moon is slightly north or south of the Sun's position because the Moon's orbit around Earth is inclined about 5° to Earth's orbit around the Sun. Twice each year, however, the Moon crosses the plane of Earth's orbit, and during these relatively brief *eclipse seasons*, eclipses take place.

The specific circumstances of a solar eclipse depend on the exact location of the New Moon in relation to the Sun and Earth. The Sun is approximately four hundred times the diameter of the Moon and, coincidentally, the Sun is about four hun-

dred times farther away from Earth than the Moon is. Thus, both the Sun and Moon have the same apparent angular size, about $1/2^\circ$, which causes the Moon's shadow to cut a narrow swath across Earth's surface. The width of the path depends on how close the Moon is to Earth (the closer the two bodies, the wider the path).

Observing an Eclipse

From the moment the Moon's limb first passes in front of the Sun's disk — appropriately called first contact — the eclipse progresses rapidly. A casual observer probably would not notice anything unusual until the Sun was about three-quarters obscured: the partially blocked Sun does not appear significantly fainter.

As the partial phase nears 90 percent, the sky and landscape darken noticeably. Eventually light from the Sun's bright photosphere passes only through valleys located along the Moon's limb, causing a display known as Bailey's Beads. Second contact is the instant at which the Sun's

disk disappears. The eclipse is then total.

Normally overwhelmed by light from the photosphere, the narrow, red-hued chromosphere appears immediately after the photosphere is covered. The soft glow of the Sun's corona becomes visible next; its shape and extent depend on the level of activity occurring on the Sun's surface. Bright stars and planets will also appear in the darkened sky close to the Sun.

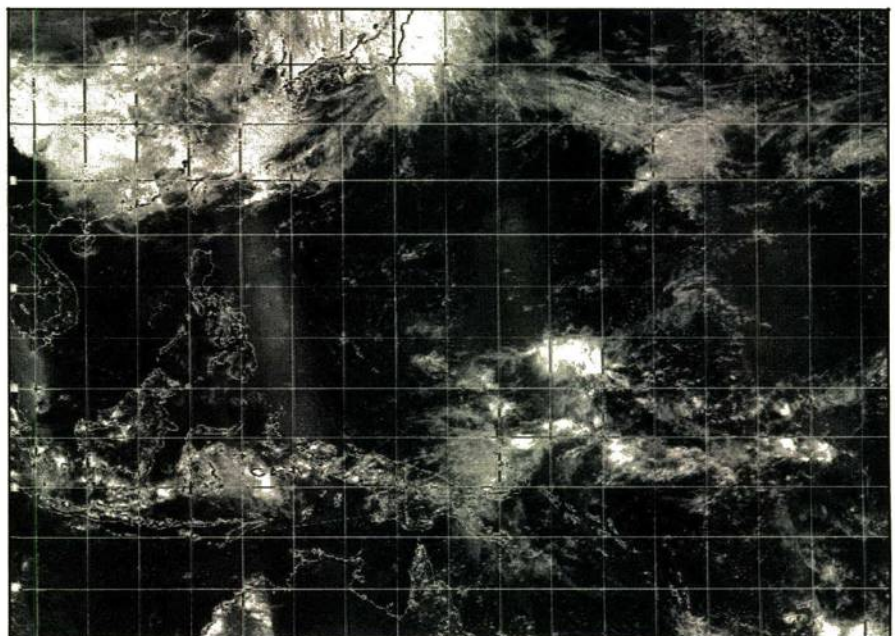
The total phase ends at third contact, when the solar photosphere reappears from behind the Moon, and fourth contact occurs when the Moon finally moves clear of the Sun's disk. The eclipse after totality is a mirror image of the eclipse before totality.

Observers outside the path of totality but within the area where the Moon blocks part of the Sun's disk see a partial eclipse of the Sun. The magnitude of the partial eclipse is greater the closer you are to the path of totality.

The Dawn of an Unusual Day

On March 18, 1988, the Sun will not

This visible-wavelength image, taken from the NOAA 9 weather satellite on the afternoon of March 24, 1987, illustrates the type of cloud patterns that might be expected during March 1988. The eclipse path is reasonably clear through the tropics, although the best conditions appear to be in the Mindanao area. Image courtesy Jay Anderson.



rise as a full disk over a small section of the eastern Indian Ocean; instead, the Sun will rise totally eclipsed by the Moon. Although totality will last less than two minutes there, the spot marks the beginning of a total eclipse path that continues for nearly 60° in latitude and over 130° in longitude.

As the Moon's shadow speeds across Earth's surface, observers along the path of totality witness a total eclipse lasting a couple of minutes. Eastward from its origin in the Indian Ocean, the path crosses the southern part of the Indonesian island Sumatra and then moves northeasterly through the Indonesian province of Kalimantan on the island of Borneo. By this time the Sun is 35° high, and the total phase is close to three minutes long. Continuing northeastward, the Sun's shadow makes its last major landfall on the southernmost Philippine island of Mindanao.

The total phase reaches a maximum length of 3 minutes and 51 seconds at approximately 20° north latitude and 131° east longitude. At this time the Sun is 65° above the horizon. The second half of the eclipse path runs generally northeast through the north Pacific, passing just south of the Aleutian Islands and ending

in the Gulf of Alaska at sunset on March 17. (The International Date Line causes this apparent jump backward in time.)

There will also be a large number of people who will see a partial eclipse. Observers from many sites in Indonesia and the Philippines, as well as in Malaysia, Singapore, and the Aleutian Islands, will see more than 90 percent of the Sun covered. And those in large portions of Southeast Asia, Japan, and Alaska will see more than half the Sun disappear. (See "Local Circumstances for Selected Geographic Locations" on page 42.)

Observing Considerations

If you are willing to spend the time and money necessary to witness this rare event, where will you have the best chance of seeing it? The weather along the path of totality is the key factor in determining where to go.

The tropics have a deserved reputation for sunny skies, and this region has the most reliably favorable sky conditions for this eclipse. The farther north you travel on the eclipse path, the more likely you are to run into cloudy weather. But choosing an exact observation site should be a personal choice based on all the available data.

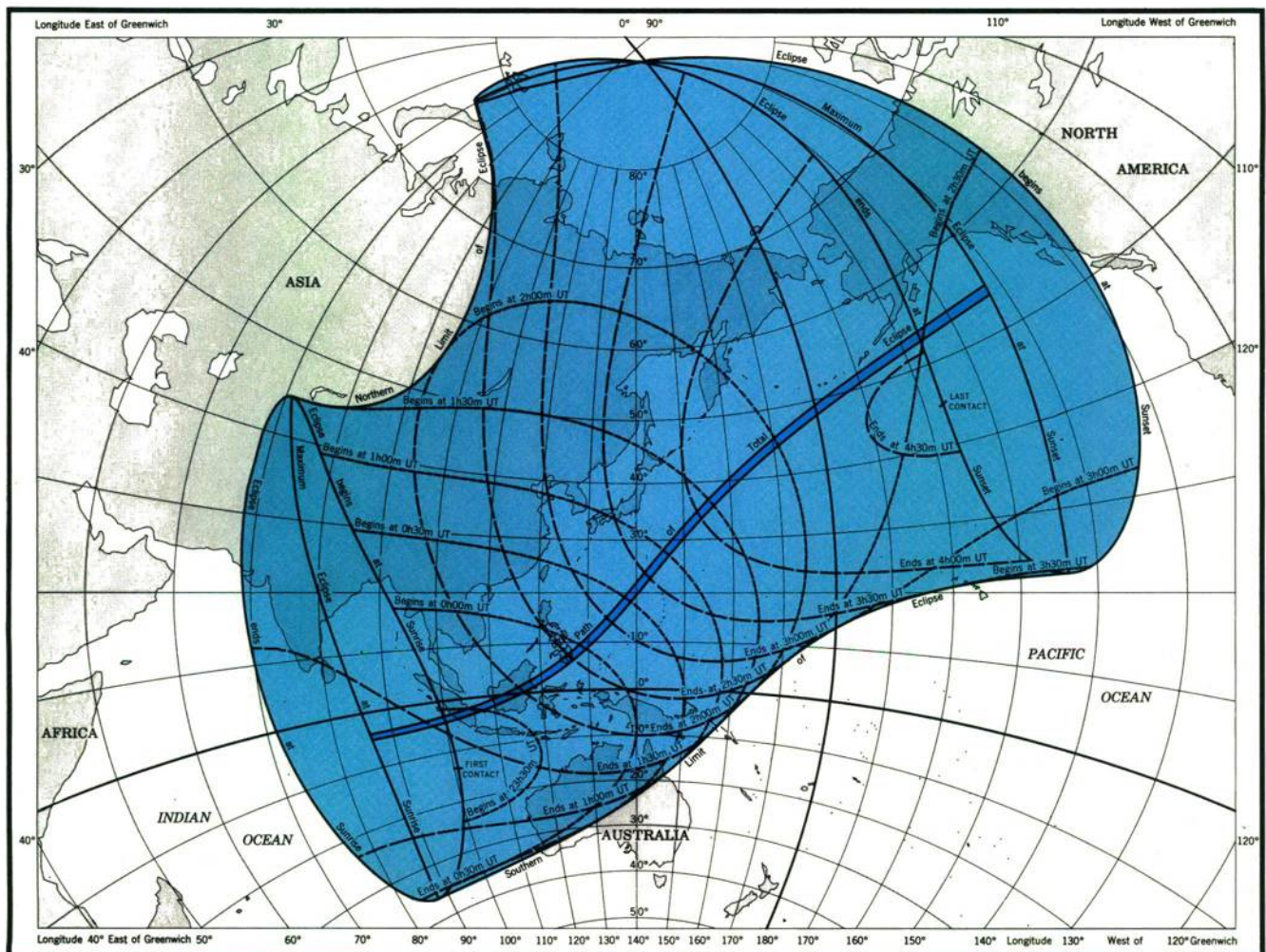
Unfortunately, there are considerations that go beyond mere weather. One of the most inviting sites from a meteorological point of view is in the Philippines, but the political situation there during the past few years has been volatile. What will happen between now and March is anyone's guess, but observing from the Philippines may not be safe.

Weather along the Eclipse Track

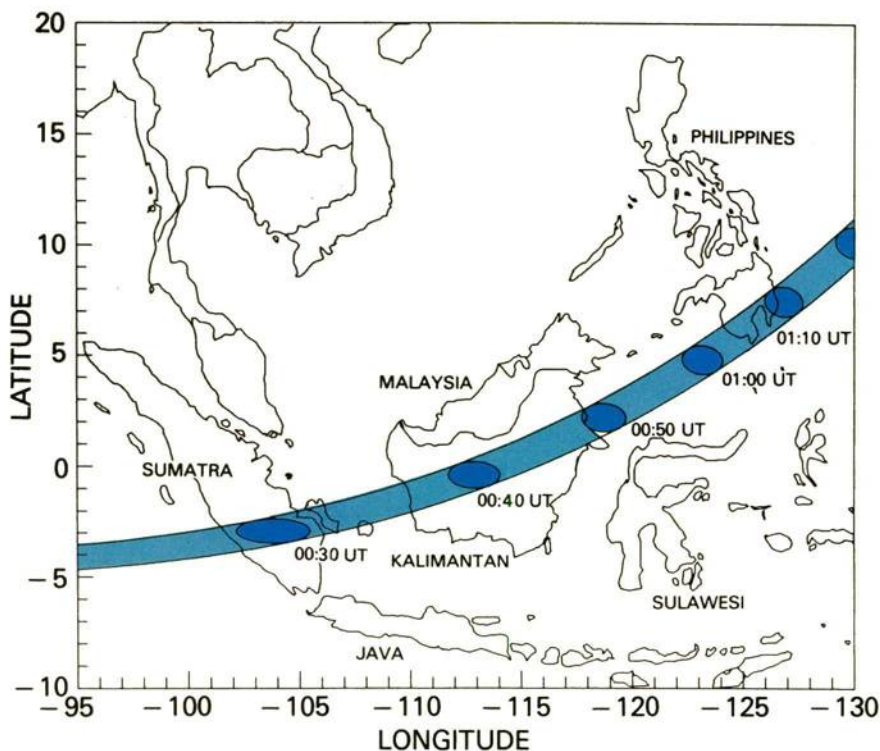
Earth's atmosphere is partitioned into several distinct zones of high and low pressure that girdle the globe and the regions of atmospheric circulation these zones generate. In March the average position of Earth's weather "equator," the Intertropical Convergence Zone (ITCZ), lies just south of the early portion of the eclipse track. The ITCZ is the region where air masses from the Northern and

Observers along the path of totality, which is shaded dark blue, will be able to see a total eclipse of the Sun next March, while those in the area shaded light blue can see only a partial solar eclipse. The curved black lines represent the universal times of the eclipse's beginning and end. Map courtesy LeRoy Doggett, U.S. Naval Observatory.

TOTAL SOLAR ECLIPSE OF 1988 MARCH 17-18



TOTAL SOLAR ECLIPSE 18 MARCH 1988



Southern hemispheres collide, causing the convective clouds and the heavy showers associated with tropical weather.

North of the ITCZ, the northeast monsoon winds take hold. These winds carry dry Asiatic air, which has been consider-

ably moistened by its passage over water, into the Philippines and bring the dry season to much of Mindanao, particularly where mountains block the steady flow of the wind.

Still farther north along the eclipse track,

A close-up of the path of totality as the path crosses three major land areas: Sumatra, Kalimantan on the island of Borneo, and Mindanao in the Philippines. The dark blue ovals represent the Moon's shadow at ten-minute intervals. Map by Fred Espenak.

where equatorial climates give way to more temperate weather, the northeast monsoon winds are replaced by the north Pacific trade winds. At eclipse time the trades should blow across the northern Philippines and along the ocean track to about 20 degrees north latitude.

Between 20 and 40 degrees north, the Moon's shadow crosses the subtropical high with its light winds and sunny skies and then enters the regime of the temperate zone westerlies. Pacific lows embedded in these westerlies bring frequent storms and cold blustery weather, which make the area south of the Aleutian Islands the most inclement along the eclipse path.

Expected Cloud Cover

Estimating the likelihood of cloud cover at a prospective observing site requires knowledge of both general weather patterns and specific weather records.

Sumatra and Borneo, the first landmasses along the eclipse track, lie close to the average position of the ITCZ and thus tend to be cloudier than other overland parts of the track. (See the "Mean Monthly Cloudiness" chart at the bottom of page 41.) Daytime cloud cover generally varies between 70 and 90 percent over Sumatra and Kalimantan, the Indonesian part of Borneo, although the ocean and terrain cause considerable variations. Because one statistic does not necessarily yield a reliable comparison of the prospects for different places, the table "Average March Weather Conditions" on page 40 lists three measures of cloudiness for locations along the path of totality.

The location along the path of totality where clear skies are most likely to occur is General Santos on the Philippine island of Mindanao. The Philippines are well north of the ITCZ and their weather is influenced by the dry, northeast monsoon winds. General Santos is one of the drier locations in the Philippines, and March is the height of its dry season.

The terrain surrounding General Santos is another factor in the city's dry and sunny weather. General Santos is bordered by mountains to the east, north, and west and open to the sea on the south. The mountains wring moisture from the prevailing northerly monsoon, and the flow of air down the lee side of the mountains further dries the air mass. General Santos is exposed to southerly winds only 4 percent of the time during March.

Statistics for Tarakan, Indonesia, suggest the east coast of Borneo may also be a good site for viewing the eclipse. Access to this region could be a major problem, however.

Winds can also play a significant role

Average March Weather Conditions

Location	High Temp. (° Celsius)	A.M. Relative Humidity	Daytime Cloud Cover (%)	Daily Hours of Sunshine	Sunny Days*
Balikpapan, Kalimantan	31	93	76	4.4	3.5
Banjarmasin, Kalimantan	31	97	87	3.4	3.2
• Bengkulu, Sumatra	32	96	74	4.4	0.7
Cotabato, Mindanao	34	77	81	6.6	8.0
• Davao, Mindanao	32	81	79	—	8.8
• General Santos, Mindanao	34	73	69	—	16.4
Jakarta, Java	31	93	81	4.1	—
Jambi, Sumatra	31	97	85	3.8	3.3
Kodiak, Alaska	2	76	70	—	5.5
Manado, Sulawesi	30	93	71	4.4	5.6
Padang, Sumatra	30	94	76	4.4	2.3
• Palembang, Sumatra	32	96	74	4.2	0.5
• Pangkalpinang, Bangka	31	95	82	3.5	2.2
Pontianak, Kalimantan	32	98	77	4.4	1.1
Sibu, Malaysia	32	98	83	5.0	—
Singapore	31	95	83	6.3	—
Tarakan, Kalimantan	31	95	70	—	3.7
Zamboanga, Mindanao	32	77	73	6.8	8.2

* Number of days in March with less than 0.3 cloud cover and visibility more than three miles during the morning hours.

• Cities in path of total eclipse.

Data courtesy Jay Anderson.

in cloud cover. Areas where winds blow downhill are particularly attractive for eclipse viewing because the air warms as it descends, which dries the air. Although winds in equatorial regions are very light, the above-surface winds generally blow from the east over the Philippines, from the west over Sumatra, and are calm over Borneo. This means the east side of Sumatra and the west and southwest sides of Mindanao are more likely to have clear skies than the opposite shores.

On average there are fewer clouds over water than over land. This is because the cumulus clouds so common in the tropics are caused by daytime heating of the ground. For those wishing to observe the eclipse from onboard ship, the portion of the eclipse path over the Celebes Sea and the region east of the Philippines are most likely to be clear.

The Celebes Sea is also attractive because it's relatively calm. As the "Mean Wave Height" chart on page 42 demonstrates, the average waves in this region are less than one meter high. In addition, there is not much variation in the wave heights — there is a two-thirds probability they will be less than about 1.5 meters.

Temperature and Humidity

Average daytime high temperatures over Indonesia and the Philippines are generally in the low 30°-range Celsius (near 90° F). Temperatures are cooler at higher altitudes, falling at a rate of about 0.6° C every hundred meters. Overnight low temperatures along the land portion of the eclipse path are in the low 20°-range Celsius (about 72° F) at sea-level sites.

The discomfort associated with high humidity may be the most telling aspect of tropical weather for those not accli-

matized to it. For comparison, a humidity of 70 percent with a temperature of 30° C, values common along the southern portion of the eclipse track, is very humid by Northern Hemisphere standards. Drier air is found at higher altitudes, especially in the Philippines.

Selecting the Eclipse Site

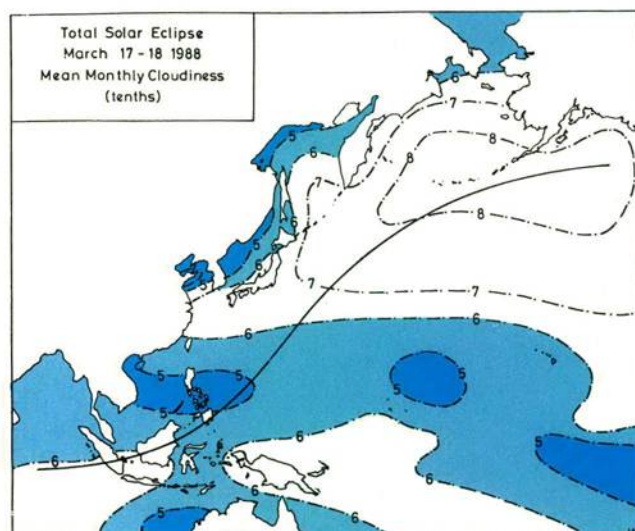
From a meteorological point of view, a tropical eclipse is a nighttime event: the clouds that form and dissipate follow a pattern driven by falling surface temperatures. The changes that occur as the eclipse progresses can be extremely rapid, and the conditions prevailing at the start of the eclipse are unlikely to be those dominating at the end of the eclipse unless skies are clear.

The most common type of cloud across the tropical portion of the eclipse path is

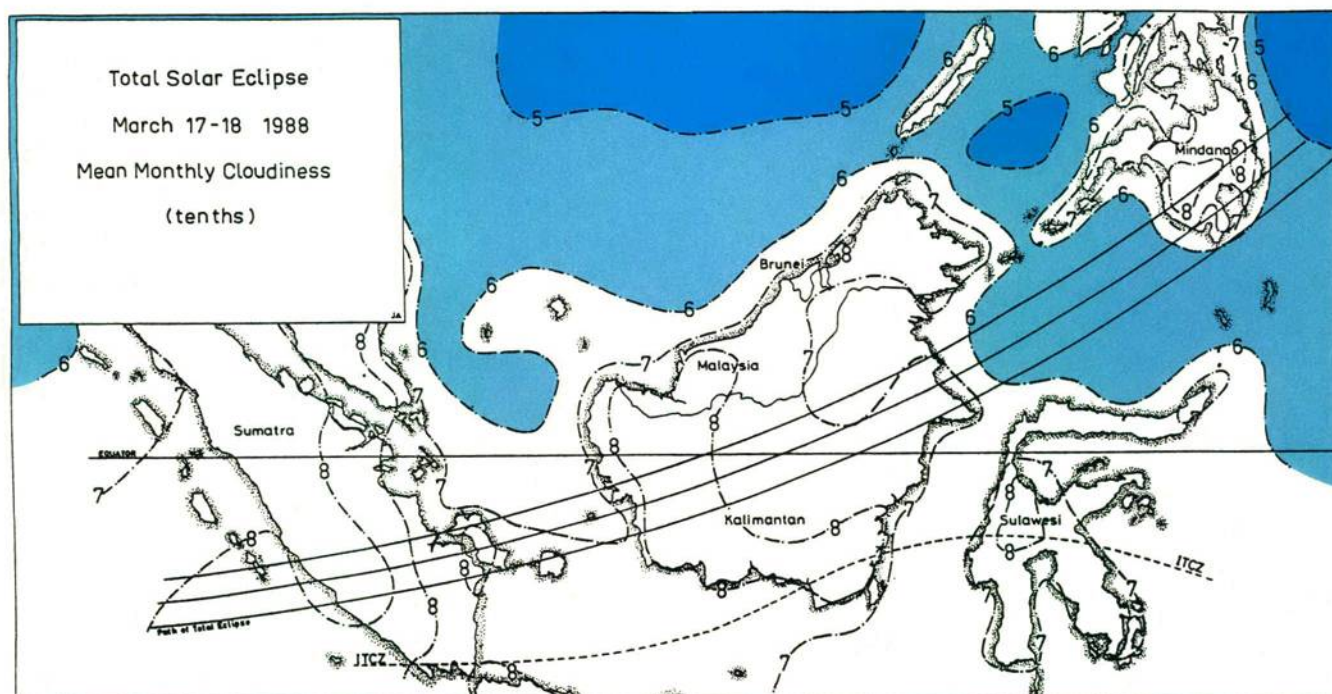
cumulus, which builds rapidly as the Sun heats the ground in the morning. This type of cloud tends to dissipate between first and second contact, as the Sun is gradually covered. Stratus clouds may form as the cumulus clouds dissipate, though generally the eclipse is too short for an extensive cloud cover to develop. An exception occurs where winds blow upslope, because this lifting further cools the air mass. This means observing conditions at some hilly locations may suddenly deteriorate just before totality.

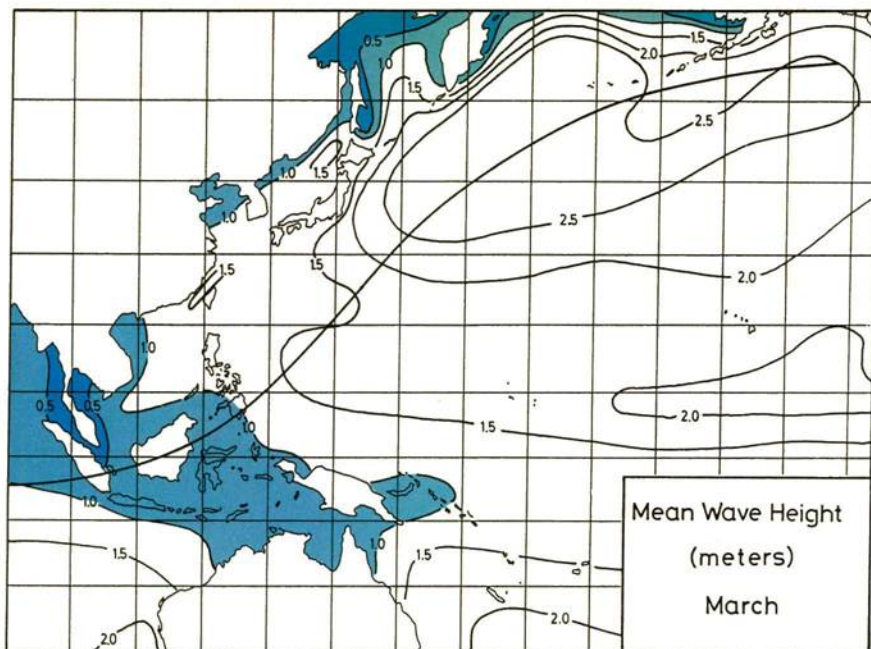
To assess the importance of the various influences on site selection, monitor weather conditions in the mornings and evenings prior to eclipse day. Night is, after all, a form of solar eclipse, and the behavior of the clouds as temperatures fall may provide you with valuable clues for

Right: Average cloudiness (in tenths) over water for a twenty-four-hour period in March. The solid line shows path of totality. Dark blue areas average less than 0.5 cloudiness; light blue regions are less than 0.6 cloudy. Maps courtesy Jay Anderson.



Below: Average cloudiness (in tenths) during daylight hours in March. The dashed line (ITCZ) shows average March position of the Intertropical Convergence Zone.





This map shows average wave heights in meters for the month of March. Areas where waves average less than 0.5-meter-high are shaded dark blue, while regions where waves average less than 1 meter are shaded light blue. The calmest seas are in the vicinity of Indonesia and the Philippines. Map courtesy Jay Anderson.

Local Circumstances for Selected Geographic Locations

Location	UT	Maximum Eclipse		Duration of Totality
		Obscur. (%)	Sun's Alt. (°)	
Anchorage, Alaska	3h25m40.3	75.5	4	
Atka, Alaska	3h23m54.6	95.6	20	
Balikpapan, Kalimantan	0h42m48.5	95.1	36	
Bangkok, Thailand	0h49m40.2	47.9	20	
Banjarmasin, Kalimantan	0h37m43.0	91.2	32	
Calcutta, India	0h55m53.4	22.6	9	
Canton, China	1h20m12.6	40.1	37	
Cotabato, Mindanao	1h05m49.1	98.4	48	
Darwin, Australia	0h43m24.9	35.3	48	
Davao, Mindanao	1h07m32.0	100.0	50	2m50.8s
General Santos, Mindanao	1h05m07.0	100.0	49	3m22.4s
Guam	1h51m38.3	71.9	73	
Hong Kong	1h19m46.3	42.9	38	
Jakarta, Java	0h28m28.6	89.3	22	
Kuala Lumpur, Malaysia	0h35m39.7	80.7	18	
Manila, Philippines	1h14m49.5	72.2	45	
Nome, Alaska	3h19m20.5	59.2	11	
Padang, Sumatra	0h30m07.5	94.1	16	
Palembang, Sumatra	0h30m30.2	100.0	20	2m12.1s
Pangkalpinang, Bangka	0h32m19.3	100.0	22	2m11.4s
Pontianak, Kalimantan	0h37m11.5	97.3	27	
Seoul, S. Korea	2h07m03.0	38.2	46	
Singapore	0h34m49.0	88.4	20	
Taipei, Taiwan	1h35m59.9	49.7	46	
Tokyo, Japan	2h23m40.4	68.1	53	
Vladivostok, U.S.S.R.	2h22m28.7	37.9	44	

Data courtesy John Bangert.

choosing a specific site.

If cumulus clouds dissipate early in the evening, particularly before the Sun has even set, then the prospects for eclipse day are favorable if no change in the overall conditions occurs. Keep a watch on the nearby hills as the Sun goes down to see where stratus clouds form most quickly, and then avoid those areas on eclipse day.

Sunrise conditions also give an indication of cloud-prone areas, though the twelve hours of overnight cooling build a more extensive cloud cover than the one to two hours of cooling associated with an eclipse. Nevertheless, early risers can get valuable clues about which areas to avoid. Both Tarakan and General Santos have a history of clearing skies overnight.

Observations of low clouds are particularly important because middle and high clouds are much less influenced by the eclipse cooling. In fact, if you see considerable high-level cloudiness at the same time the eclipse will take place, the odds of being clouded out are greater. Learning to recognize the general types of clouds will help you assess prospective viewing sites.

Another important pre-eclipse observation you should make is the wind direction above the surface. You can do this by simply watching the motion of the clouds, though winds are relatively light in the tropics and seeing the motion may take some time. Once you have determined the wind direction, position yourself so the winds are blowing downhill toward you for the eclipse.

Which is the Best Site?

Unfortunately, there is no unequivocal answer to this question. Strictly from a meteorological standpoint, the best land-based site is General Santos in the Philippines. But the east coasts of both Borneo and Sumatra are also likely to have clear skies.

Observing from a ship has one advantage over observing from land — the ship can move easily. Cloud cover over the tropical oceans is rarely solid and there are usually holes in the clouds nearby, so a mobile ship can generally find a clear spot. The best sea-based observation sites should be in the Celebes Sea southwest of Mindanao.

The tropics are, above all else, very sunny, and eclipses there are more likely to be seen than in most other parts of the world. The weather situation for March 1988 is just slightly worse than it was for the June 1983 eclipse, and very few people were clouded out of that one. With careful planning most people who make the effort to see this eclipse will be rewarded with an awe-inspiring view.

Jay Anderson is a meteorologist with the Pacific Weather Centre in Vancouver, British Columbia. He has provided eclipse weather information to the U.S. Naval Observatory for the past several years.

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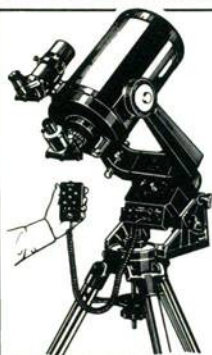
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Perseids Contend with Moonlight

by Robert Burnham

The Wanderers

This month's evening sky contains only two planets. Right after sunset, **Saturn** is visible to the naked eye. (Uranus and Neptune lie nearby but can be identified only with a telescope.) As twilight fades into night, Saturn, along with the star Antares to its lower right, is the first object you see in the south.

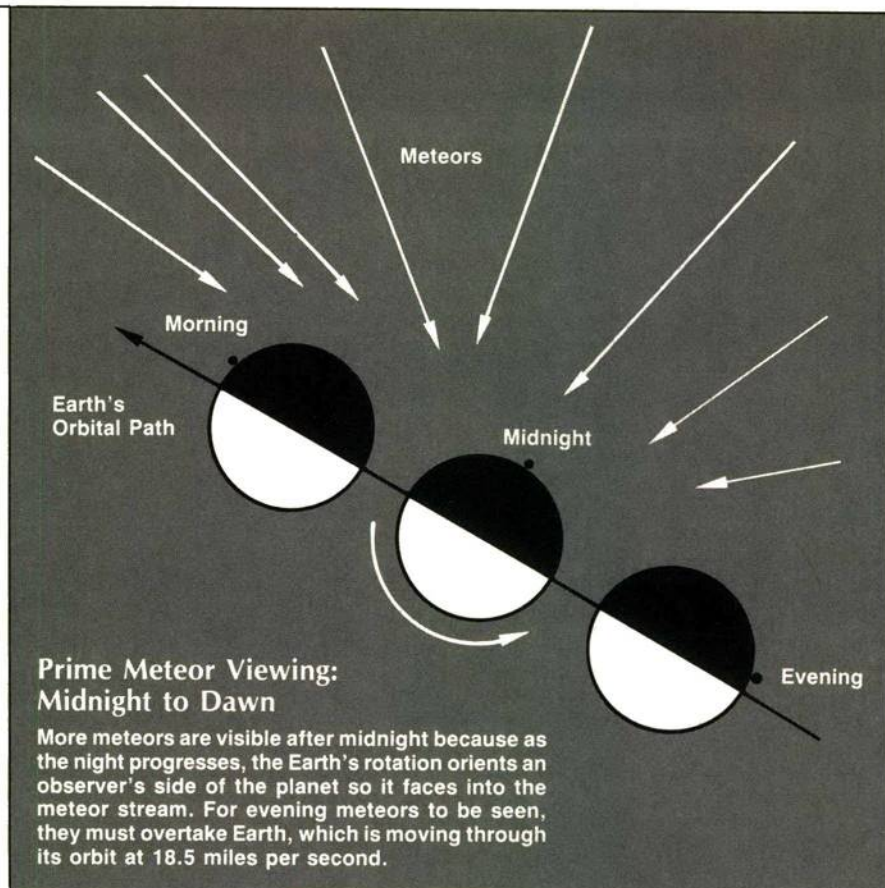
Saturn's brightness is 0.3 magnitude; Antares' is 0.9. To tell which is which, remember that Saturn is higher, whiter in color, and slightly brighter. On the evenings of the 3rd, 4th, and 5th, a waxing gibbous Moon will glide past Saturn and Antares, brightening the sky and banishing the fainter stars with its light.

If you wait up till midnight, you will see tonight's only other bright planet, **Jupiter**. It rises around 10 or 11 p.m. but usually takes another hour or two to climb over the houses and trees that clutter the foreground. Jupiter is bright and easy to find, moonlight notwithstanding: it shines brilliant white at magnitude -2.6. Moreover, its region of the sky lacks any bright stars to rival it the way Antares challenges Saturn. (If you're an early riser, you can also see Jupiter as morning twilight begins. Look for it high in the south more than halfway between the horizon and overhead.)

The morning sky also provides the only chance to see **Mercury** this month. During the first week of August this hard-to-see planet is visible very low in the east-northeast in the hour before sunrise. Starting at about 7° elevation on the 1st, Mercury will lie a little lower each day thereafter. Mercury's magnitude is -1.4, and it usually looks reddish ivory in color. Binoculars will help you spot it.

By August 10, Mercury will be too low to be seen. After superior conjunction

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.



with the Sun on the 20th (when the planet is behind the Sun and cannot be seen from the Earth), Mercury will move into the evening sky, becoming visible there about two weeks later.

Venus and **Mars** are both too close to the Sun for viewing this month and most of next month. Venus is in superior conjunction on August 23 and will be out of view until late September, when it appears low in the western sky after sunset. Mars reaches conjunction with the Sun on August 25 and will appear in the morning sky in mid-September.

Sad to say, the Moon will largely preempt this year's **Perseid meteor shower**, at least for photographers (see Skylore). Peak meteor activity comes in the late evening hours of August 12 and the early morning of the 13th, when the lunar phase is three days past Full. With a waning gibbous Moon lighting the skies, long-exposure photos are impossible.

While photography is out, the Perseids will nevertheless interest naked-eye viewers. Arm yourself with bug repellent and sit outside in a lawn chair facing northeast. Have a blanket or sleeping bag handy should the night turn chilly. As the shower radiant, which lies between Cassiopeia and Perseus, climbs above the trees, relax and enjoy the show. If local light pollution is minimal, you may see as many as twenty of the characteristically swift Perseids an hour. (Best views come after 1 a.m., however, when Earth's rota-

Opposite page: A needlelike Perseid meteor splits the sky over Owensboro, Kentucky, during the 1986 shower. Charlie Manion used a 24mm lens at f/2.8, ISO 400 Ektachrome film, and an 8-minute exposure.

tion carries your side of the planet into the oncoming meteor stream.)

The Starry Sky

Every August many people find themselves, perhaps for the first time in years, under a truly dark sky. Seeing a sky full of stars is overwhelming. But whether you're miles from civilization or standing in your own backyard, learning the sky is easy.

At the end of evening twilight, face south and then look straight overhead, where a bright white star catches your eye. This star is Vega, located in **Lyra** the Lyre, a small constellation that looks like a squashed rectangle. (Lyra looks bigger in the sky than it does on the star map because the map must squeeze the entire sky into a 10-inch circle.)

A short way to the left of Vega is another star about as bright: Deneb, which marks the tail feathers of **Cygnus** the Swan. The rest of Cygnus forms a cross pointing south. Below Cygnus a third white star looks a little dimmer than Vega: this is Altair in **Aquila** the Eagle, a constellation



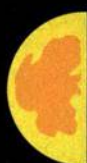
August Night Sky



First Quarter
August 2
3:24 p.m. EDT



Full Moon
August 9
6:17 a.m. EDT



Last Quarter
August 16
4:25 a.m. EDT



New Moon
August 24
7:59 a.m. EDT



First Quarter
August 31
11:48 p.m. EDT

- 2nd** First Quarter Moon occurs at 3:24 p.m. EDT.
- 4th** The waxing gibbous Moon makes a triangle with Saturn and Antares in the evening sky (see diagram below).
- 8th** The Moon is closest to Earth at 3:20 p.m. EDT: 222,229 miles (357,633 kilometers).
- 9th** The Moon is Full at 6:17 a.m. EDT. It will set in the southwest as dawn lightens the sky.
- 12th** The annual Perseid meteor shower reaches peak activity this year in the mid-evening hours (see text for details).
- 13th** The Moon lies near Jupiter late this evening (see diagram on page 51).
- 16th** Last Quarter Moon is at 4:25 a.m. EDT.
- 20th** Mercury passes through superior conjunction. It will reappear low in the western sky after sunset in about three weeks.
- 21st** The Moon is farthest from Earth at 10:37 a.m. EDT: 252,355 miles (406,114 kilometers).
- 23rd** Venus is at superior conjunction and lost in the Sun's glare. It will become visible in the evening sky in about a month. Look for it low in the west.
- 24th** The Moon is New at 7:59 a.m. EDT.
- 25th** Mars is in conjunction with the Sun and will remain invisible until late next month.
- 31st** First Quarter Moon occurs at 11:48 p.m. EDT.



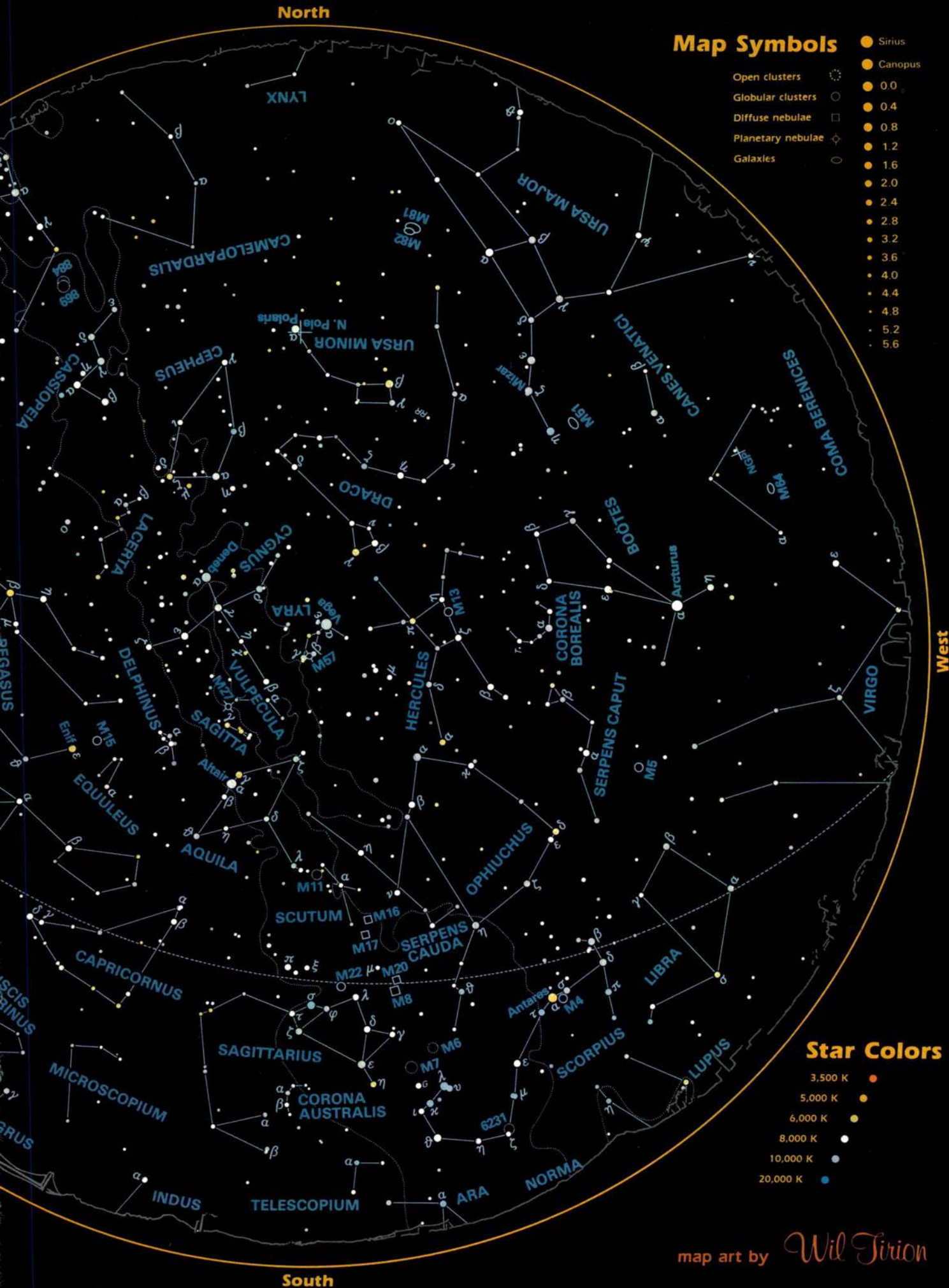
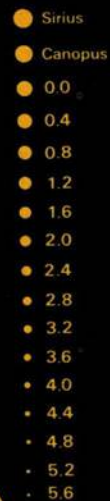
The
Star Dome
shows how the
sky looks at:

11:30 p.m. on August 1
10:30 p.m. on August 15
9:30 p.m. on August 31



Map Symbols

- Open clusters
- Globular clusters
- Diffuse nebulae
- Planetary nebulae
- Galaxies





that dates back to the early Mesopotamian civilizations. Together Vega, Deneb, and Altair form "The Summer Triangle," a large, simple figure prominent at this time of year.

Under dark skies you can see that Cygnus and Aquila lie in the haze of the **Milky Way**. This sparkly path is formed by countless stars too faint to be distinguished individually, as a glimpse with binoculars shows. Its real form is fairly regular, but the split that begins in Cygnus and continues south of the constellation is caused by an intervening "local" cloud of dense interstellar dust.

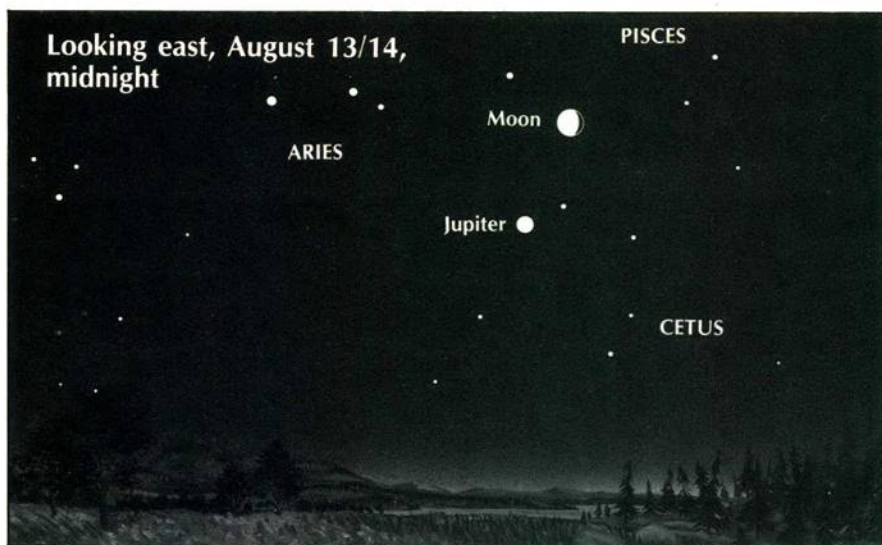
Below Aquila your eye falls naturally on a group of stars that resembles an angular-edged teapot. Known as **Sagittarius** the Archer, the "teapot" and other stars make up a figure from Mesopotamian mythology. The Archer lies in the zodiac, a group of twelve figures along the ecliptic, the imaginary line (shown as dashes on the map) that traces the yearlong apparent path of the Sun among the stars. Today most people see Sagittarius as a teapot with Milky Way "steam" coming out its spout.

To the right of Sagittarius is **Scorpius**, another zodiacal figure. Ruddy Antares is the Scorpion's only bright star, but the planet Saturn, which lies nearby, might confuse you. Scorpius curls south and east with its barbed stinger at Lambda (λ). Following the ecliptic east from Sagittarius, we encounter **Capricornus** the Sea Goat, a broad triangle of 3rd- and 4th-magnitude stars hard to discern except under a dark sky. Rising behind Capricornus is the Water-Bearer **Aquarius**, which is even harder to trace because it lacks even the rough symmetry of the Sea Goat.

Let's return to the sky overhead. To the right of Vega stands **Hercules** the Strongman, a keystone-shaped figure with arms and legs extended. Below Hercules (as you face west) the bright star Arcturus marks the feet of the Herdsman **Bootes**, which is adjacent to semicircular **Corona Borealis** the Northern Crown. Looking to the left of Hercules and Bootes, you'll see the large bell-shaped figure of **Ophiuchus** the Serpent-Bearer holding **Serpens** the Snake. (Saturn at present is in Ophiuchus' southernmost part.) The head of the Snake (Serpens Caput) lies toward Arcturus, and the tail (Cauda) reaches into the Milky Way.

Looking overhead once more follow the Milky Way down to the northern horizon from Cygnus. First we encounter **Lacerta** the Lizard, a dim zigzag figure that is pretty easy to see under a dark sky. Then comes **Cepheus**, King of Ethiopia, a figure looking more like a warped home plate than a king! The tip of Cepheus lies toward Polaris, the North Star, part of **Ursa Minor** the Lesser Bear. (The Great Bear **Ursa**

Opposite page: The occultation of Venus by the Moon on April 25, was captured in this shot by Barney Magrath with Kodachrome 64-speed film.



Major — the Big Dipper — is setting in the northwest.)

Cepheus' queen was **Cassiopeia**, a Milky Way figure rising in the northeast. Seated on a highly uncomfortable looking throne, Cassiopeia is bent into a "W" shape. Her daughter **Andromeda** stands to Cassiopeia's right and is attached to **Pegasus** the Flying Horse, a large diamond figure rising in the east. We'll see these two figures much better when autumn's frosty nights arrive.

Skylore

Ages ago meteors were thought to be unlucky stars that slipped from their places in the sky. Indeed, we still speak of "falling" and "shooting" stars. Yet meteors and stars have little in common: the bright, fast streak of a Perseid, for example, comes from only a few grams of dust about as substantial as cigarette ash. Hitting the atmosphere at speeds of about 40 miles per second, this fluff is heated by friction to incandescence. After leaving a bright streak perhaps a dozen miles long, a meteor fades out.

Some meteors, Perseids among them, are also known to leave dim glowing trains in their paths, a faint visible echo that disperses after a few seconds. On occasion a really large meteor — weighing an ounce or two — will shine brighter than Jupiter, producing a fireball. (If the fireball breaks into several pieces, it's called a bolide.) Fireballs are a real treat because they're usually bright enough to cast shadows. Seeing your surroundings abruptly lit up by a moving celestial light is an experience you'll long remember!

Meteors of all sizes zip into the atmosphere all the time — roughly 200 million of them a day worldwide. Most of these are in random orbits around the Sun and thus appear anytime and streak in from all directions. For this reason they are called "sporadic" meteors; you can see about ten of them an hour on any dark, moonless night.

At certain times of the year meteor "showers" appear with great regularity. These showers feature many meteors that appear to come from one particular region of sky. This region, called the "radiant," bestows a name on the shower: the meteors of August 12 are called the Perseids because the radiant lies in Perseus. (In some Catholic countries, the Perseids are also known as "St. Laurence's tears," because St. Laurence was martyred on August 10.)

Shower radiants were discovered fairly recently. In fact, the event that stimulated astronomers to study meteors was the great Leonid "storm" of November 1833, when an estimated one thousand meteors streaked the sky every minute. (A similar display occurred in November 1966.) The flow of meteors out of Leo was evident to anyone who saw the shower.

The apparent divergence is simply a perspective effect. The meteors move in parallel paths and appear to diverge from a point in space only in the sense that a railroad track or a road opens up as you travel down it. The stream of the Perseids is so large, however, that the Earth takes several days to traverse just its densest part. The total Perseid stream lasts from late July until mid-August — a very wide stream indeed.

In 1867 Giovanni Schiaparelli (the Italian astronomer who first noted a pattern of straight lines on Mars that he termed *canali*) discovered that the Perseid meteors orbited the Sun in a path nearly identical to that of Comet Swift-Tuttle (1862 III). This discovery laid the foundation of meteor astronomy. Today we believe comets are the source of all meteors, whether the meteors are shower members or sporadics.

Going out every August to enjoy the night of the Perseids is one of summer's great delights. The cooler evening air and the chill dew that descends late both hint at the onset of autumn. The sky is magnificent and the meteors spark as brightly as they have for ages past. Who could ask for more?

ASTRONOMY

Reviews

The Search for Extraterrestrial Intelligence: Listening for Life in the Cosmos

Thomas R. McDonough
244 pages, cloth, \$19.95
John Wiley & Sons (1986)
ISBN 0-471-84684-8

"There's a very good chance that, in the next few years, the reader will see the first proof of extraterrestrial beings in the headlines of all the world's newspapers."

Depending upon your knowledge of the ongoing search for extraterrestrial intelligence (SETI) and your personal biases, you might consider the above statement absurd, agree wholeheartedly with it, or have an opinion somewhere between the two extremes.

The author, Thomas McDonough, doesn't equivocate about his stance. His book is an overview of SETI, aimed at those who are unacquainted with the notion that life on Earth is not unique in the universe. As coordinator of SETI for the Planetary Society and a lecturer at Caltech, his authority carries some weight.

McDonough's book insists that extraterrestrials exist and that contact with them, either at our instigation or theirs, could be imminent. The book begins with a historical overview that examines the early proposals addressing the question about our uniqueness in the cosmos. McDonough points out that the viewpoints of those who pondered Earth's exclusivity were unpopular. For example, Giordano Bruno, a fifteenth-century Italian priest who believed there may be an infinite number of life-harboring worlds, was burned at the stake for his convictions.

McDonough offers numerous examples of how the early searchers planned to communicate with extraterrestrials. One fanciful project was building huge mirrors across the breadth of Europe to flash signals to Mars. Plans to set afire a great, twenty-mile-wide ditch filled with kerosene, thus sending a pyrotechnic greeting, were also considered. Yet another pro-

posal called for planting trees in a geometrically significant pattern to let alien beings know intelligence exists on our planet.

The author then describes the notions science fiction writers have expressed about extraterrestrials in such classic works as *War of the Worlds*, *Star Maker*, and *The Martian Chronicles*. The last work, written by Ray Bradbury, was one of the first to break tradition with its literary predecessors because the Martians were depicted as friendly rather than as hostile. McDonough also discusses the various roles of aliens in popular science fiction movies like *Destination: Moon*, *The Day the Earth Stood Still*, *Forbidden Planet*, and *2001: A Space Odyssey*.

Finally, in the fourth and fifth chapters, the book gets solidly under way, investigating the origins of life on Earth and speculating about mankind's future ventures in the solar system. McDonough believes that if we understand how life evolved here, our extraterrestrial search will be easier. Given that life on Earth is so abundant, looking for life within the solar system makes sense. He is reluctant to rule out the possibility that some form of life exists on the other planets. In fact, he sees the Sun's family as relatively accommodating to various forms of terrestrial life.

His optimism about searching for life in our solar system dismisses formidable obstacles, such as the hostile conditions on the satellites around Jupiter, with such conviction it's hard not to believe anything is possible. "Eventually," he writes, "a Jacques Cousteau may swim deep inside Europa under the dark, eerie ice cover. The diver's lights will stab through the gloom and the explorer will see with his or her own eyes whether there are other creatures swimming there."

Just how likely is an encounter with extraterrestrial intelligence? One possible indicator is the well-publicized *Drake Equation*, devised by the American astronomer and SETI pioneer, Frank Drake. The equation attempts to estimate

the number of extraterrestrial civilizations in the Galaxy. Though it doesn't claim to be accurate, the Drake equation nevertheless helps introduce the novice SETI reader to the magnitude of the problem.

Contemporary SETI methods are discussed, including radio telescopes and space probes. Touched upon briefly are international SETI, privately funded SETI, and scientists opposed to SETI.

The volume includes scores of photographs, drawings, and SETI-related cartoons. Also included are four pages of color plates featuring many familiar Viking and Voyager images of the planets and the Galilean and Saturnian satellites.

McDonough's lighthearted approach resembles that of an enthusiastic, persuasive salesperson who is sold on and deeply involved with his product. Non-technical, undemanding, and well-written, the book is a good primer on SETI. *Gail O. Clark.*

International Directory of Professional Astronomical Institutions 1987

A. Heck and J. Manfroid
276 pages, paper, 120 francs
[Publisher's address: Observatoire Astronomique Centre de Données Stellaires 11, rue de l'Université 67000 Strasbourg, France]

As its title indicates, this book is a directory of all the major astronomical institutions of the world, including current addresses and telephone numbers, plus, in some cases, the primary fields of research being conducted at those institutions.

Gravity, Gauge Theories, and Quantum Cosmology

Jayant V. Narlikar and T. Padmanabhan
468 pages, cloth, \$97
ISBN 90277-1948-9
D. Reidel (1986)

Quantum theory and the special theory

of relativity represent revolutionary advances in physics. However, their coexistence has been turbulent at best. This book is an attempt to legitimize the "offspring" of these two theories — quantum field theory. The authors highlight the interdisciplinary problems between these theories (quantizing gravity, for example) and offer a simplified version of quantum gravity and cosmology and how they apply to problems of the early universe.

Divided into four parts, this book covers field theory and gauge fields, general relativity and cosmology, quantum field theory in curved space-time, and an introduction to quantum gravity.

Satellites

Joseph A. Burns and
Mildred Shapely Matthews, eds.
1,021 pages, cloth, no price given
ISBN 0-8165-0983-2
University of Arizona Press (1986)

Few scientific fields have blossomed as prolifically as that of planetary satellites. Nowhere is this more graphically illustrated than in *Satellites*, the outcome of a "Natural Satellites" conference of the International Astronomical Union held at Cornell University in July 1983.

This comprehensive work features maps of all the major satellites, including a pull-

out map of Io. Topics covered include "Origins of Satellites," "The Tectonics of Icy Satellites," "The Physical Characteristics of Satellite Surfaces," "Cratering of Planetary Satellites," and chapters addressing the Moon, Io, Europa, and the satellites of Saturn.

Bernard Lovell

Dudley Saward
314 pages, cloth, \$21.95
ISBN 0-7090-1745-6
Salem House Publishers (1986)

Bernard Lovell is a biography of the venerated English astronomer who was the first professor of radio astronomy at Manchester University and largely responsible for establishing the 250-foot radio dish at Jodrell Bank.

God and Nature

David C. Lindberg and
Ronald L. Numbers, eds.
516 pages, paper, \$17.95
ISBN 0-520-05692-2
University of California Press (1986)

Subtitled "Historical Essays on the Encounter between Christianity and Science," Lindberg and Numbers' book is a provocative collection of papers on

the relationship between Christianity and science. The various authors cover the period from the early Christian church to the twentieth century. Appraisals are offered on the trial of Galileo, the formulation of a Newtonian worldview, Darwinism, the Creationists, and modern physics and Christian faith.

Upper Main Sequence Stars with Anomalous Abundances

C. R. Cowley, M. M. Dworetsky,
and C. Megessier, eds.
489 pages, cloth, \$95
ISBN 90-277-2296-X
D. Reidel (1986)

This volume contains papers presented at the International Astronomical Union Colloquium number 90 at the Crimean Astrophysical Observatory in May 1985. It covers chemically peculiar stars of the upper main sequence.

Whitney's Star Finder

Charles A. Whitney
107 pages, paper, \$12.95
ISBN 0-394-72717-7
Alfred A. Knopf (1985)

This revision of the famous field guide to the sky shows the reader how to rec-

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Nucleosynthesis and Its Implications on Nuclear and Particle Physics

Jean Audouze and Nicole Mathieu, eds.
502 pages, cloth, \$79
ISBN 90-277-2173-4
D. Reidel (1986)

Nucleosynthesis is a compilation of papers addressing major problems in our understanding of how heavy elements are created in the nuclear reactions of stars. This series was sponsored by the NATO Advanced Science Institutes. Titles include "The Puzzle of Lithium in Evolved Stars," "How Degenerate Can We Be?," "Type I Supernovae," "Optical Supernova Remnants," and "Can Neutrinos from Cygnus X-3 Be Seen by Proton Decay Detectors?"

The Evolution of Galactic X-Ray Binaries

J. Truemper, W. H. G. Lewin, and W. Brinkmann, eds.
309 pages, cloth, \$54
ISBN 90-277-2184-X
D. Reidel (1986)

This volume is a collection of papers spawned by a conference on x-ray binary sources that was sponsored by the NATO Advanced Science Institutes. Topics include the role of binaries in the evolution of globular clusters, orbital periods of massive x-ray binaries, the evolution of Hercules X-1, the orbital periods of low-mass x-ray binaries, and the decay of neutron star magnetic fields.

Backyard Astronomy

Alan MacRobert
21 pages, paper, \$3.95
ISBN 0-933346-44-1
Sky Publishing Corp. (1986)

A series of reprinted articles from *Sky & Telescope* Magazine form this introductory booklet on astronomical observing.

Cool Stars, Stellar Systems, and the Sun

Michael Zeilik and David M. Gibson, eds.
501 pages, cloth, \$46.50
ISBN 3-540-16763-3
Springer-Verlag (1986)

Cool Stars is the proceedings from a 1985 workshop held in Santa Fe, New Mexico. Among the papers are "Stellar Pulsation, Atmospheric Structure, and Mass Loss" by L. A. Willson and G. H.

Bowen; "The Short-Period RS CVn Systems: A Preliminary Starspot Analysis" by M. Zeilik and E. Budding; "Photometric Variability of Main-Sequence Stars from Wilson's Survey" by G. W. Lockwood and B. A. Skiff; and "Marginal BY Draconis Stars" by B. W. Bopp.

Astronomy and Astrophysics Abstracts, Volume 40, Part 2

Inge Heinrich and Lutz D. Schmadel, editors-in-chief
1,096 pages, cloth, no price given
ISBN 3-540-16655-6
Springer-Verlag (1986)

Astronomy and Astrophysics Abstracts is an ongoing listing of the abstracts from international papers concerning all aspects of astronomy and astrophysics published in the world's refereed research periodicals. Volume 40 records the abstracts for literature published in 1985 and received before February 1986.

Seismology of the Sun and the Distant Stars

D. O. Gough, ed.
479 pages, cloth, \$79
ISBN 90-277-2196-3
D. Reidel (1986)

Contained in this book are the 1985 proceedings of a workshop on seismology of the Sun and distant stars, held at Cambridge, England.

New Worlds: In Search of the Planets

Heather Couper with Nigel Henbest
144 pages, paper, \$12.95
ISBN 0-201-11316-3
Addison-Wesley (1986)

This is a popular-level book about the solar system, encompassing the Moon, planets, asteroids, comets, and ideas about planetary formation. Included are chapters on the birth of the planets, asteroids and comets, the search for Planet X, the Moon, and the nine planets themselves.

Quasars

G. Swarup and V. K. Kapahi, eds.
605 pages, cloth, \$110
ISBN 90-277-2297-8
D. Reidel (1986)

Quasars is the proceedings from a 1985 symposium on QSOs held at Bangalore, India. Among the papers are "A New Catalogue of Quasi-Stellar Objects" by A. Hewitt and G. Burbidge; "Evolution of the Compact Radio Source 3C 345" by J. Biretta, M. Cohen, and R. Moore; "Optical Brightness Monitoring of the Twin QSO Q0957+561 A,B" by R. Schild; and "A Close Look at Q 2237+0305" by J. A. Tyson.

Halley: le roman des cometes

Anny-Chantal Levasseur-Regourd and Philippe de La Cotardiere
289 pages, paper, no price given
ISBN 2-207-23160-7
Editions Denoel (1985)
[Publisher's address: 19, rue de l'Université, Paris, France]

This popular-level French book provides a historical and observational review of Halley and comets in general.

Darwin's Universe, 2nd edition

Charles R. Pellegrino and Jesse A. Stoff
238 pages, paper, \$14.95
ISBN 0-8306-2773-1
TAB Books (1986)

Subtitled "Origins and Crises in the History of Life," *Darwin's Universe* examines the early history of Earth, proto-organic chemistry, and molecular biology. It goes on to discuss planetary landscapes and atmospheres, the extinction of dinosaurs, and Soviet-American spaceflight politics.

The Hall of Heavenly Records

Joseph Needham, Lu Gwei-Djen, John H. Combridge, and John S. Major
201 pages, cloth, \$44.50
ISBN 0-521-30368-0
Cambridge University Press (1986)

This book is a detailed analysis of Korean astronomical instruments and clocks made between the years 1380 and 1780.

Impact Earth

1/2" VHS or Beta videotape, \$189
16mm film, \$495
Southerby Productions (1986)
[Publisher's address: 5000 East Anaheim Street, Long Beach, CA 90804]

This 52-minute video cassette, rentable for ten days for \$50, examines the evidence for early meteoritic impacts on Earth and the possible effects on the world today and in the future of these impacts.

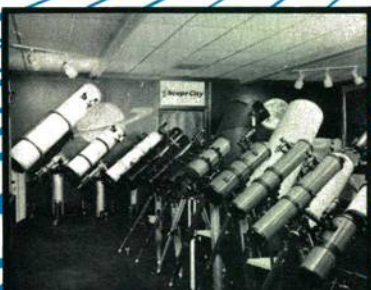
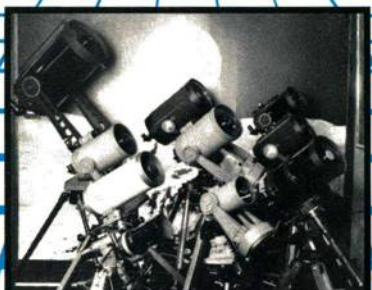
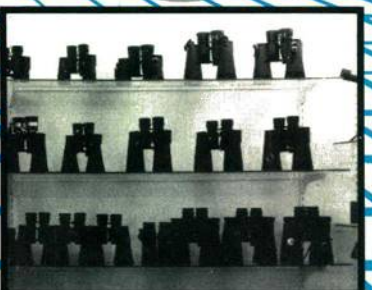
Astrophysics of Brown Dwarfs

Minas C. Kafatos, Robert S. Harrington, and Stephen P. Maran, eds.
276 pages, cloth, \$49.50
ISBN 0-521-32337-1
Cambridge University Press (1986)

The proceedings of a workshop held in 1985 at George Mason University in Fairfax, Virginia, *Brown Dwarfs* contains such papers as "The Astrometric Detection of Brown Dwarfs" by Robert S. Harrington, "The Role of the Space Telescope in the Detection of Brown Dwarfs" by William A. Baum, and a conference summary by John N. Bahcall.

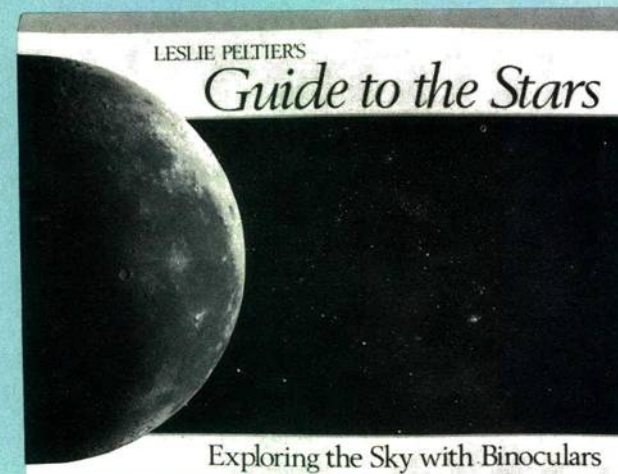


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Tips for Shooting Clusters and Nebulae

by Matthew F. Willson

Deep-sky observers have it easy. Night after night they go outside to observe their favorite nebulae and star clusters and never think about the fundamental differences between these types of objects. Deep-sky observers are lookers. They look and sometimes they make sketches of what they've seen.

Astrophotographers are a different lot. When you photograph deep-sky objects, you find that each type of object demands a different combination of lens, film, and filter for the best results. The same system that yields masterful results on the Pleiades may record the Lagoon Nebula as a dull blob. To produce pleasing photographs of all types of deep-sky objects, you need a carefully planned combination of lens, film, and filter for each type of object.

Open Clusters

Open clusters are composed of stars and usually contain no nebulosity, so you normally don't need a filter to photograph them. However, if you are photographing from a moderately light-polluted site, a dark blue filter can help eliminate stray light — specifically green, yellow, and red emission lines produced by high-pressure sodium (pink) streetlights — and increase the contrast between the sky and stars. A blue filter isn't a cure-all for light pollution however, because mercury-vapor streetlights have emission lines in blue. Furthermore, high-pressure sodium lamps emit weakly over the entire spectrum between ultraviolet and green.

Open star clusters are made up chiefly of young, intrinsically bright stars that emit much of their light in the blue and green parts of the spectrum. A large portion of this light also lies in the ultraviolet. This light can be photographed, but it is invisible to the eye. Try using a blue Wratten 47 or 47B filter on your next batch of cluster photos. This won't completely eliminate light pollution, but on these bluish objects a blue filter will allow you to expose longer than you could without a filter.

When you use a strong color filter such as one of the Wratten 82 series, don't use

color film. If you do, the entire image will take on the color of the filter. Instead, use a black-and-white film that records blue light effectively. You may have read about Tech Pan 2415's wonderful reputation for recording red objects like emission nebulae, but you may not know that its "blue response" is as good as that of many other films. In addition, its fine grain and high contrast (and high speed when properly hypersensitized) make it an excellent choice for shooting open clusters. The old standard, Tri-X, will also record open clusters well. Kodak's 103a-0 spectroscopic film was practically created for shooting bluish astronomical objects, although its grain is much coarser than that of Tech Pan.

If you want to use color film, try a light blue Wratten 80A filter. Although it won't block much light pollution, it can increase the contrast between cluster members and the sky background. Under a dark sky an 80A filter increases contrast and suppresses emission nebulosity surrounding an open cluster. This is particularly useful if you wish to record only the stars in, say, the Rosette Nebula.

Choosing a color film will take you on one of two paths. Fujichrome RD 100 provides a slightly reddish background;

Ektachrome 400 tends to give a bluish background. Konica SR 1600 also has excellent blue response, but it is relatively grainy and yields low-contrast images.

Now that you know about which films and filters to use, what about a lens? For stars the most important lens consideration is aperture. Two lenses of equal aperture record star images at the same rate, regardless of their f/ratios or focal lengths. A 50mm f/2 lens with an aperture of 25mm will capture stars at the same rate as a 100mm f/4 lens with a 25mm aperture. However, the f/4 lens allows you to expose film four times longer than the f/2 lens does before the picture is ruined by "fogging," or an overexposed sky background. Thus, an f/4 lens can record stars about 1.5 magnitudes fainter than an f/2 lens of the same aperture.

Remember, though, that when you stop a lens down, you are reducing its aperture. You may think that if you stop down your 135mm f/3.5 lens to f/8, you'll record the same star images but with less fog. This isn't true. At f/8 the lens will record stars about five times slower than it would at f/3.5. To reach the same limiting magnitude, you would have to expose five times as long.

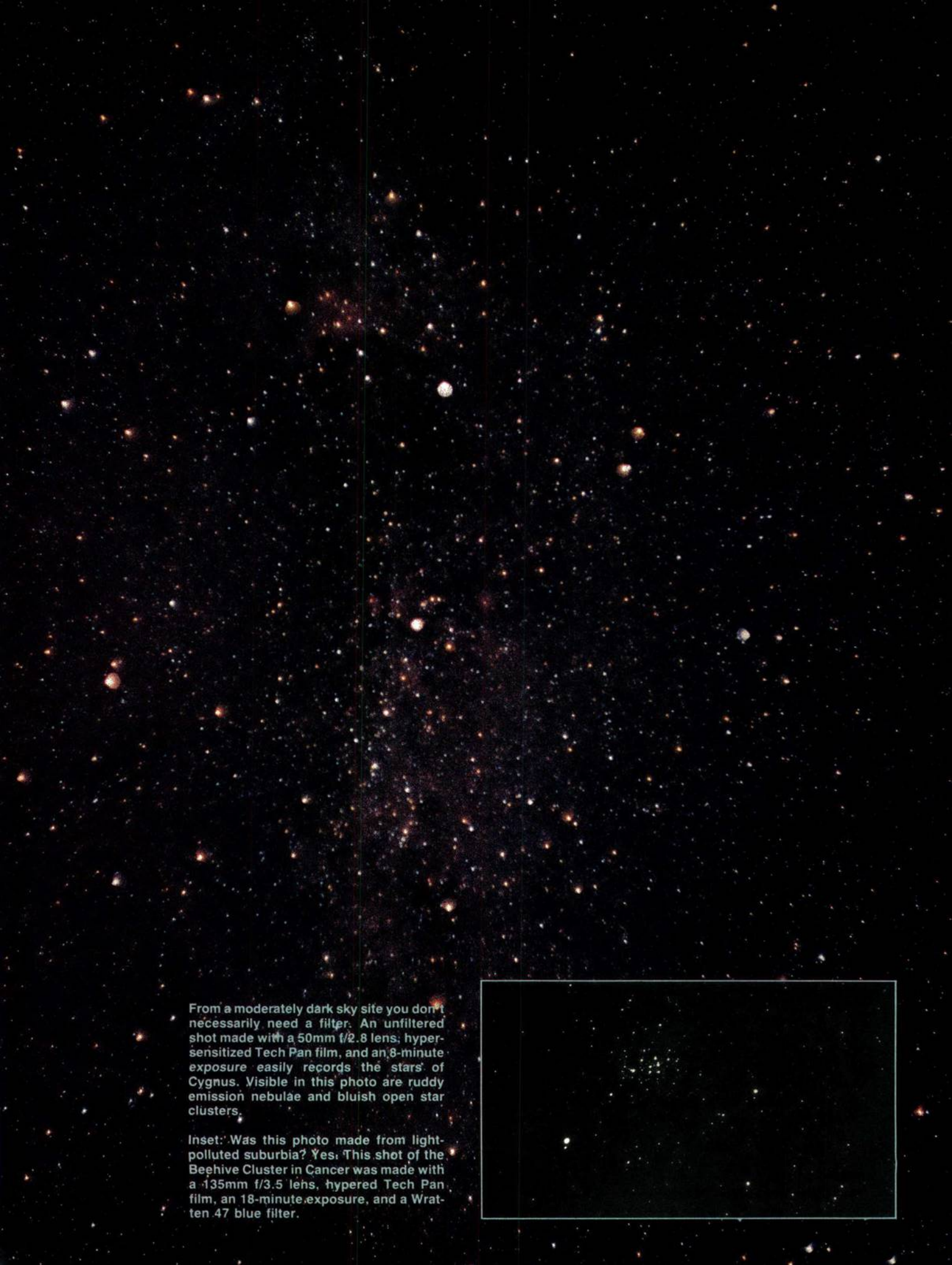
Instead of stopping down, use a lens





Photographing nebulae and clusters with a filter can reduce light pollution and produce stunning results. This photograph of the western half of the Veil Nebula, NGC-6960, was made with a 20-inch f/5 reflector, chilled Fujichrome 400 film, an LPR filter, and a 30-minute exposure. Photo by Jack Newton.

Opposite page: A filter that is too strongly colored, however, can produce a washed-out, oddly tinted picture. This shot of Orion was made with a Wratten 15 filter on Ektachrome 400 film. This shot and the photos on pages 58 and 59 are by Matthew Willson.



From a moderately dark sky site you don't necessarily need a filter. An unfiltered shot made with a 50mm f/2.8 lens, hypersensitized Tech Pan film, and an 8-minute exposure easily records the stars of Cygnus. Visible in this photo are ruddy emission nebulae and bluish open star clusters.

Inset: Was this photo made from light-polluted suburbia? Yes. This shot of the Beehive Cluster in Cancer was made with a 135mm f/3.5 lens, hypered Tech Pan film, an 18-minute exposure, and a Wratten 47 blue filter.



with a longer focal length. This will provide a relatively large aperture at $f/8$. For example, a 300mm $f/8$ lens has an aperture of 37.5 mm, nearly the same as the 135mm lens at $f/3.5$. You will be able to use a longer exposure and record more.

Reflection Nebulae

Like open clusters, reflection nebulae are bluish in color. Why? When light from stars strikes a dust cloud, the longer, redder wavelengths pass through the cloud and we don't see them, whereas the blue wavelengths are scattered and reflected back toward us by tiny dust grains.

Although reflection nebulae are much fainter than star clusters, the film and filter choices you make are the same as for open clusters. Lens choice is another matter, though. Because reflection nebulae are not point sources but extended objects that often have low surface brightnesses, your camera system's f /ratio determines how long you must expose the film. Aperture is now relatively unimportant. Because you'll want to reduce your guiding time to a minimum, use a lens with a low f /ratio. Remember, when you double the f /ratio, you quadruple the exposure.

While point sources like stars do not get any bigger if you use a long focus lens, nebulae do. Be sure to use a lens that will record the details you want the picture to show. Although longer is always better, a focal length between 100mm and 300mm is adequate for starters.

Emission Nebulae

Emission nebulae are clouds of hydrogen gas that glow because of ultraviolet radiation from a nearby star. The cloud emits photons of light at various wavelengths. The light we can see best is the H-alpha line at 6563 angstroms, in the deep red portion of the visible spectrum. It follows, then, that the best filters for recording emission nebulae are deep red filters like a Wratten 25 or 92.

From a suburban location the combination of a 92 filter and a red-sensitive black-and-white film is perfect for emission nebulae. The filter blocks most light pollution except for a few weak mercury lines and the weak red continuum from high-pressure sodium lamps, which greatly increases contrast.

The best film to use with red filters is Tech Pan 2415. Its red sensitivity, fine grain, and high speed when hypered make it the number one choice. Second place belongs to the spectroscopic emulsions 103a-E and 103a-F. 103a-E has an edge because it is slightly more sensitive to red light. Both are grainy compared with Tech Pan, however. Tri-X is unimpressive on emission nebulae because its red sensitivity is low; it does not hypersensitize well, either.

If you use color film, your filter choices are rather limited. Try a light red Wratten 85 or 21, or a similar light red filter. These filters block very little light pollution, but



they do increase the contrast between the nebula and sky.

Several color films record emission nebulae especially well. Hypered Fujichrome 100 works well and has a very fine grain. Regular Fuji 400 was changed several years ago and is no longer red-sensitive enough for astrophotography. Fuji Professional 400 D, however, was not changed and it is one of the best color films. It has good speed even when unhypered, excellent color rendition, and medium grain. Konica SR 1600 is fast even unhypered, and it records red nebulae well. But its contrast is low and its grain coarse.

When you shoot clusters and nebulae, the right combination of film, lens, and filter can give you precisely the photographic results you want. Whether you are spending a relaxing evening in the back-

Above: Before and after. At the top of the page is an unfiltered photograph of Orion's sword, showing a bright sky background, bloby star images, and poor contrast. The photo below it, made from the same location with a Wratten 25 filter, is a dramatic improvement. Both shots were made with a 135mm $f/3.5$ lens and hypered Tech Pan film.

yard shooting the Pleiades or guiding a 90-minute exposure of the Veil Nebula from the top of a 12,000-foot peak, a photographic system chosen for the right type of light will give you results guaranteed to make you a happy astrophotographer.

Matthew F. Willson is an amateur astronomer living in Littleton, Colorado. His last article for ASTRONOMY was "Camera Lenses for Astrophotography," which appeared in the August 1986 issue.

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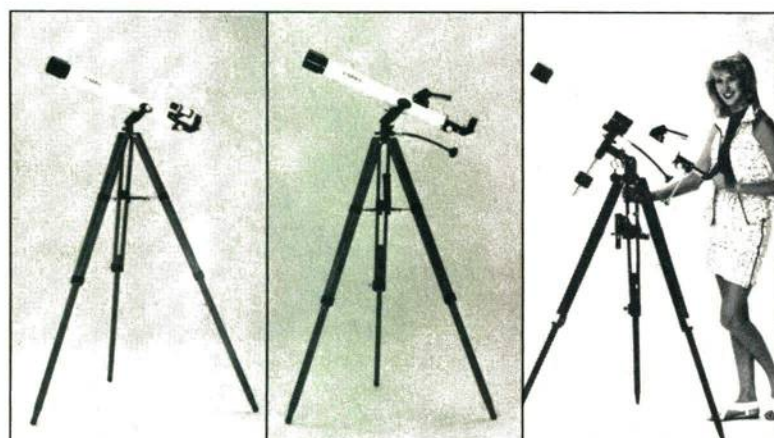
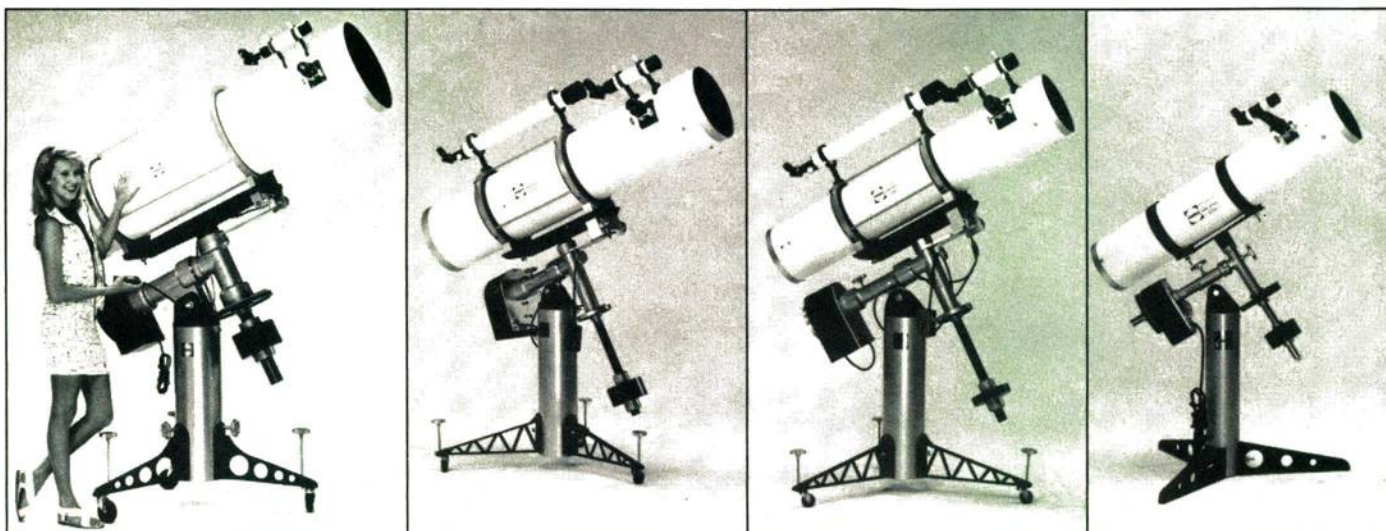
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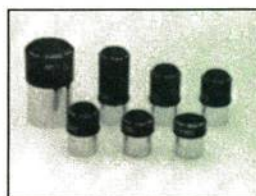
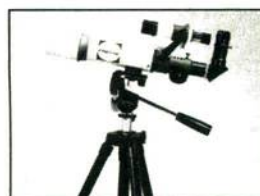


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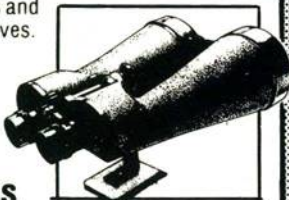
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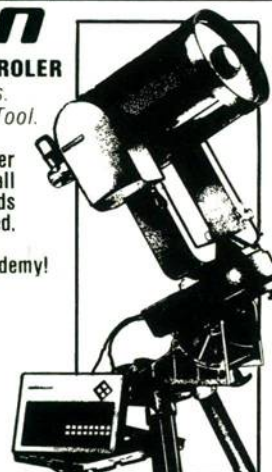
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First Space Shuttle Flight Postponed

The Space Shuttle will not begin flying again in February 1988, as scheduled, but in June 1988. According to Admiral Richard H. Truly, NASA's associate administrator for space flight, additional testing of the Shuttle's external fuel tank and main engines will delay the first launch.

The impact of the delay on scheduled missions will not be known until a new flight manifest is prepared this fall.

The European space program has also experienced delays getting off the ground since the launch failure of an Ariane 2 rocket on May 30, 1986. Flights are now scheduled to resume this August with the launch of an Ariane 3 rocket from the Guiana Space Center in South America.

Satellites Help in Study of Ancient Civilization

NASA researchers are studying Mexico's Yucatan Peninsula, central Guatemala, and Belize with satellites to find out more about the ancient Mayan civilization.

Geographic factors — particularly water — most likely shaped the Mayan civilization and played some role in the expansion and decline of the civilization. The researchers at NASA's Ames Research Center in Mountain View, California, are looking for Mayan water sources and comparing their locations to the sites of ancient ruins.

Landsat data shows that Mayan settlements in the northern Yucatan were built along faults and fracture zones in the earth, which provide access to subsurface water and have the best soil in the region. Previously scientists had not thought the topographical features were differentiated enough to affect Mayan settlement patterns.

SEASAT data has turned up what appears to be an ancient river plain extending across Guatemala, which could



Comet Wilson was still too faint to be seen by the naked eye (magnitude 6.5) on March 28, when the European Southern Observatory's 1-meter Schmidt telescope at La Silla, Chile, captured the comet in this 30-minute exposure. A long gas tail of ionized atoms and molecules almost 7 million miles long streams away from the coma toward the southwest. A very short dust tail is visible to the left (north) of the coma. By early May the comet had brightened to magnitude 5. ESO photo.

explain the location of Tikal, a major trade and ceremonial center, now in a remote, land-locked area. The now dry riverbed could provide evidence of a changing climate and explain why the Mayas abandoned major centers in this area during the tenth century.

The researchers have also investigated satellite images of the northern coastline of the Yucatan peninsula and can see marks of former coastlines beneath the water. The rising of the sea level halted Mayan salt trade and closed coastal settlements. It may also have affected agriculture far inland.

Surface water sources and their distribution, along with ground-based studies of climate changes, could lead to a measurement of how much water had been

available to the Mayas. This would lead to determinations of which areas were best for agriculture and how many people the land could have supported, which would shed light on periods of Mayan decline.

Adler Planetarium Introduces 20-Inch Telescope

Visitors to the weekly Friday evening sky show at Chicago's Adler Planetarium can now view live images of globular clusters and galaxies through a new 20-inch computer-controlled telescope without leaving the planetarium theater. Images from the telescope are projected onto an 18' by 24' area of the planetarium dome. The telescope itself is housed in the

Doane Observatory, located just east of the planetarium.

"We can actually jump around the sky and look at five or six objects in a half-hour session because the computerized controls move the telescope from one object to another in 30 seconds or less," says the planetarium's assistant director, James Sweitzer.

Because the observatory is located in downtown Chicago, some means of enhancing faint objects and coping with excessive light pollution was required. The telescope is equipped with a charge-coupled device — an ultrasensitive light detector about thirty times more sensitive than photographic emulsion. In addition, special light-pollution filters are placed between the telescope and the CCD camera to block out the sodium and mer-



Adler Planetarium's new 20-inch computer-controlled telescope relays real-time images of celestial objects into the planetarium theater. The computer system is visible in the background below the telescope's eyepiece. Two guidescopes — a 6-inch refractor and a 5-inch refractor — are mounted on top of the main tube.

cury lights of the city.

"The observing system lets us see objects 7 million times fainter than can be seen with the naked eye," says Sweitzer.

Once an object is located in the telescope, an exposure of usually one or two minutes is made (depending on the object's brightness) and then the image is projected into the theater. Although the image quality is not as refined as a long-exposure photograph, the audience sees more detail this way than by looking through the telescope without the CCD.

Sweitzer believes the telescope will not only enhance the kind of programming offered at Adler Planetarium but will also raise public awareness about how modern astronomy is conducted.

"This is how astronomers work today," says Sweitzer. "The days of the astronomer freezing in the dome while looking through a telescope are over."

Mars Observer Launch Delay Official: 1992

A last-ditch lobbying effort on Capitol Hill and the offer of a privately funded rocket have failed to keep NASA's Mars Observer mission on course for a 1990 launch. Ultimately, the impact of the mission's budgetary slowdown, begun last year after NASA tentatively announced plans to delay the launch until 1992, made a 1990 launch unattainable despite possible Congressional funding of a rocket for the mission.

According to NASA officials, Mars Observer was delayed because the level of available funding was not adequate to get the mission ready to launch by 1990. Although a crowded Shuttle schedule contributed to the postponement, switching the mission to another launch vehicle would not have preserved the original launch date.

A unique offer intended to keep the earlier launch date was proposed in March by Orbital Sciences Corporation, the contractor building the Mars Observer upper stage booster that will send the craft into interplanetary orbit. The company proposed to fund the construction of a Titan 3 rocket — at a cost of over \$60 million — that would have been ready for a 1990 liftoff. NASA would then reimburse OSC once NASA received funding for the project. NASA, however, turned down the OSC offer.

According to Bruce Murray, former director of the Jet Propulsion Laboratory and vice president of the Planetary Society, "NASA had no reason to delay the Mars Observer except for its preoccupation with marketing the Shuttle and Space Station." Murray and other Planetary Society officers, including Cornell astronomer Carl Sagan, testified before Congressional appropriations committees concerning NASA funding and policies.

"The delay of the mission is inconsistent with the widely recognized need for a new exploratory goal and the exploration of Mars as a focus for NASA," said Sagan. "This is one further indication of the low priority NASA places on space science and planetary exploration."

The fate of NASA's budget for the next fiscal year and of funding for new expendable rockets for the agency is currently in the hands of Congressional authorization and appropriations committees. An approved fiscal 1988 budget is expected in September.

Warm Infrared Galaxy Discovered behind SMC

Astronomers have discovered that a source detected by the Infrared Astronomical Satellite (IRAS) in 1983 is a highly unusual active galaxy. In the February 15, 1987, issue of the *Astrophysical Journal*, astronomers Jay Frogel of Kitt Peak National Observatory and Jonathan H.

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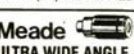
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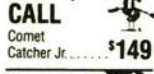
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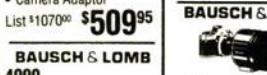
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Elias of Cerro Tololo Interamerican Observatory reported their detection of an "unusually warm galaxy" lying behind the Small Magellanic Cloud (SMC). They correlated the galaxy with a previously known infrared source called IRAS 00521-7054, until now thought to be a star inside the SMC because of its great infrared emission.

"It was a serendipitous find," according to Frogel. "We were looking at infrared sources in the Cloud and noticed that one source was a galaxy beyond the Cloud. We were surprised to find one, since galaxies are usually much cooler, and, in fact, our observing criteria are designed to exclude galaxies."

Further observations with the Cerro Tololo 1.5- and 4-meter telescopes revealed this object has a total infrared brightness some 650 billion times greater than the Sun. According to Frogel, this is "comparable to the most luminous objects known — the quasars and the IRAS bright galaxy sample."

In addition to its unusual brightness in the far-infrared part of the spectrum, IRAS 00521-7054 is also among the reddest known galaxies. This fact cannot be explained by light from old, red stars (there couldn't be enough of them to explain the redness) but must be attributed to the reddening of starlight as it passes through a thick veil of dust.

The most interesting aspect of this new galaxy for astrophysicists is its strange nucleus. "We see almost no evidence of starlight in the nucleus," Frogel says, "but we see a great deal of highly excited gas, which denotes an active galactic nucleus." Because the galaxy appears to be no more than a bright nucleus composed of gas, Frogel believes astronomers may be "seeing the first of an entire class of galaxies, which, optically, you would not suspect of being very energetic, but where you find huge amounts of infrared."

The galaxy is baffling to astronomers because it does not conform to the standard model for an active galaxy. Many astronomers hypothesize that active galaxies form from a collision of two galaxies that creates a single, giant "starburst" galaxy. As this starburst galaxy evolves, it becomes a system with incredibly high levels of energy and activity within its nucleus. But, according to Frogel and Elias, IRAS 00521-7054 shows none of the usual signs of a merger between two galaxies. If this galaxy has undergone a merger with another, the event happened so long ago that all traces of the collision have faded.

Discounting the possibility of a recent merger, the astronomers conclude that IRAS 00521-7054 appears to represent "a late stage in the transition from starburst galaxy to active galaxy, where the central, nonthermal source dominates the luminosity, but where gas and dust are still present."

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Annual OTAA Convention (sponsored by the Astronomy Club of Akron and the University of Akron), Auburn Science Center, University of Akron, Akron, Ohio. Contact: Lauri Kunkel, 131 Oakdale Avenue, Akron, OH 44302. Phone: (216) 762-5748.

August 14-16

17th Annual Niagara Frontier Council of Amateur Astronomical Association Summer Seminar (sponsored by the Syracuse Astronomical Society, Inc.), Vesper, New York. Contact: Denise Sabatini, 342-1/2 Chestnut Street, North Syracuse, NY 13212. Phone: (315) 458-1454 weekends and evenings.

August 20-24

4th Annual Mount Kobau Star Party (observing, telescope-making and astrophotography contests, speakers), Okanagan Valley, British Columbia, Canada. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T-1P4.

August 21-22

STARFEST '87 (6th annual observing convention sponsored by the North York Astronomical Association), River Place Campground, eight miles north of Mount Forest, Ontario. Contact: STARFEST '87, Andreas Gada, 145 St. George Street #701, Toronto, Ontario M5R 2M1.

August 21-23

4th Annual Mountain Astronomers Rendezvous and Star Party (sponsored by the Denver Astronomical Society and the Southern Colorado Astronomical Society), Royal Gorge Park, Canyon City, Colorado. Contact: Stefan C. Perrine, 7510 King Street, Westminster, CO 80030.

August 21-23

5th Connecticut River Valley Astronomers' Conjunction (three-day weekend of Milky Way viewing, lectures, camping), Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Road, Springfield, MA 01118.

August 29-September 27

Space Imagery Exhibit (celestial photography, space equipment, sponsored by the City of Lancaster Museum/Art Gallery, Lancaster, California. Contact: Norma Gurba, 44801 North Sierra Highway, Lancaster, CA 93534. Phone: (805) 948-8655.

September 18-20

8th Annual Astrofest (sponsored by the Chicago Astronomical Society), Camp Shaw-Naw-Nas-See, sixty miles south of Chicago, Illinois. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477.

September 25-26

N.I.A.G. Fest '87 (sponsored by the Northern Indiana Astronomical Group: Warsaw, Michiana, and Fort Wayne Societies). Holiday Inn, Warsaw, Indiana. Contact: Alan Mitterling, RR #3, Box 331A, Warsaw, IN 46580.

October 2-4

AstroAssembly 1987/Northeast Regional Astronomical League Convention (sponsored by Skyscrapers, Inc., the Astronomical Society of Rhode Island), Seagram Memorial Observatory, North Scituate, Rhode Island. Contact: Brian Magaw, Town Farm Road, P.O. Box 325, Pascoag, RI 02895. Phone: (401) 568-8424.

October 3-4

3rd Meteor Space Meeting, Amsterdam, Holland. Contact: Mark P. Traa, Meteor Magazine, Mosbeek 26, 5501 BD Veldhoven, Holland.

October 8-10

Great Plains Planetarium Association Meeting, Omnisphere Earth-Space Center, Wichita, Kansas. Contact: Jose Olivarez, Omnisphere Earth-Space Center, 220 South Main, Wichita, KS 67202.

October 18-31

Peru Revisited (three-part field trip sponsored by the Astronomical League). Leaves from Miami. Registration deadline: September 16. Contact: Cynthia Crittenden or Laura Stanley, Travel and Transport, St. Joseph, MO. Phone: 1-800-821-9010, in Missouri 1-800-892-9035.

October 23-25

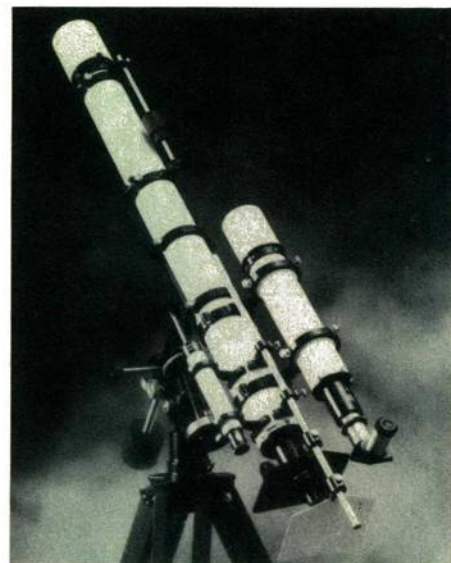
Deep South Regional Stargaze (sponsored by the Jackson Astronomical Association), Percy Quinn State Park, McComb, Mississippi. Contact: Jeff Sommers, 414 Woody Drive, Jackson, MS 39212. Phone: (601) 982-2388 days, (601) 372-2275 evenings.

October 24

Astronomy Rendezvous and Conference 1987 (sponsored by the Twin City Amateur Astronomers), Illinois State University, Normal, Illinois. Contact: Carl J. Wenning, Physics Department Planetarium, Illinois State University, Normal, IL 61761-6901. Phone: (309) 438-8758.

AstroCalendar notices must be submitted at least four months in advance of the date of the event.

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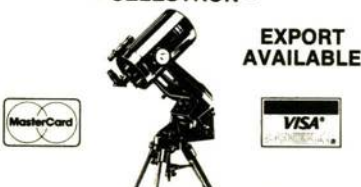
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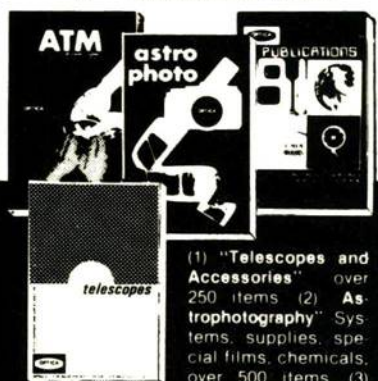
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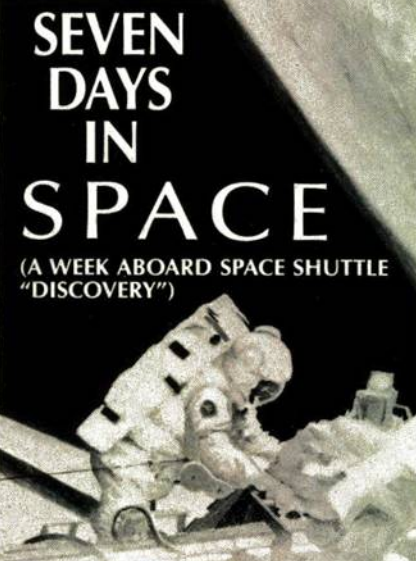
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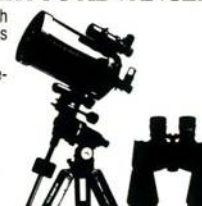
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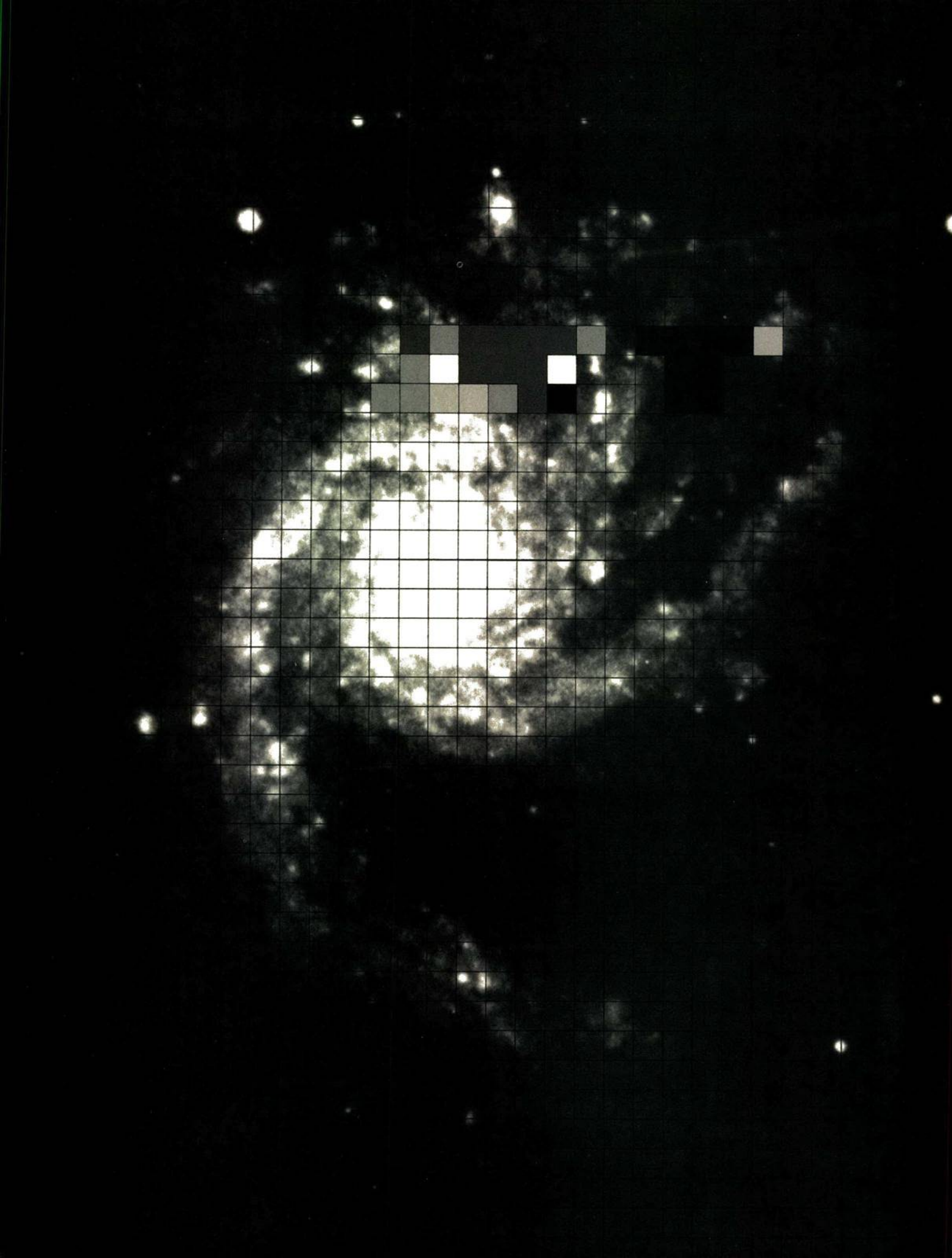


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Searching for Supernovae: The Discovery in M-99

by Carl Pennypacker

Seventy million years ago a massive star exploded in the spiral galaxy M-99. The star had run out of fuel to use in its nuclear fusion process and, as massive stars do, it blew up. Without the fusion-generated heat to support the weight of the star, gravity scored an inevitable victory. The dying star's central core, as massive as our Sun, fell in upon itself at one-tenth the speed of light, stopping only when the core had been compressed to a sphere just miles across. Under intense pressure atomic nuclei gave way, disintegrated, and poured forth a flood of neutrinos. Although neutrinos are tiny, massless particles, their number was so great that the energy they carried was equal to that put out by all the stars, quasars, and black holes in the universe. The galaxy had, for just one second, a star as energetic as a trillion trillion stars.

As the neutrino storm eased, some of the energy released by the collapsed core remained in the star's outer layers. With newfound energy individual nuclei in these layers compressed to form new, heavier nuclei. Elements like nitrogen, carbon, oxygen, and iron were created and hurled into space. Eventually these elements were doubtlessly recycled into new stars, planets, or maybe even new life. In addition, the energy of the outer layers caused the layers to expand away from the star. Ten solar masses of material from the star shot into the galaxy at 5,000 miles per second. The star was as brilliant as an entire galaxy.

As light from the supernova traveled through space, it was bright enough to be noticed by inhabitants of any galaxy it swept past. When the explosion first shook M-99, dinosaurs were enjoying their last few million years of existence on Earth and mammals were the size of chipmunks. But the light took 70 million years to reach us, time enough for a group of twentieth-century scientists in Berkeley, California, to put together a supernova search project that picked up the light on May 16, 1986.

The Berkeley Experiment

Twenty years ago when the first light from the M-99 supernova reached the distance of the star Vega, searching for supernovae among distant galaxies was a hot topic in astronomy. At this time physicist Stirling Colgate, one scientist among many studying the methods of supernova searching, attempted to define the best method for systematic searching. He knew that in a single galaxy a super-

nova is a rare event that occurs perhaps once per century. However, monitoring many galaxies greatly increases the chances of seeing a supernova: if you watch one hundred galaxies, you'll see about one supernova per year. If you watch 5,200 galaxies, you'll see one every week. Looking at this many objects would require many telescopes and astronomers. That is, unless the search is automated.

In 1979 a simple idea proposed by some great scientists started an experiment in supernova searching at the Lawrence Berkeley Laboratories in Berkeley, California. A team of scientists began using state-of-the-art computers and imaging devices to attempt to discover a supernova. The team — Carl Pennypacker, Shane Burns,

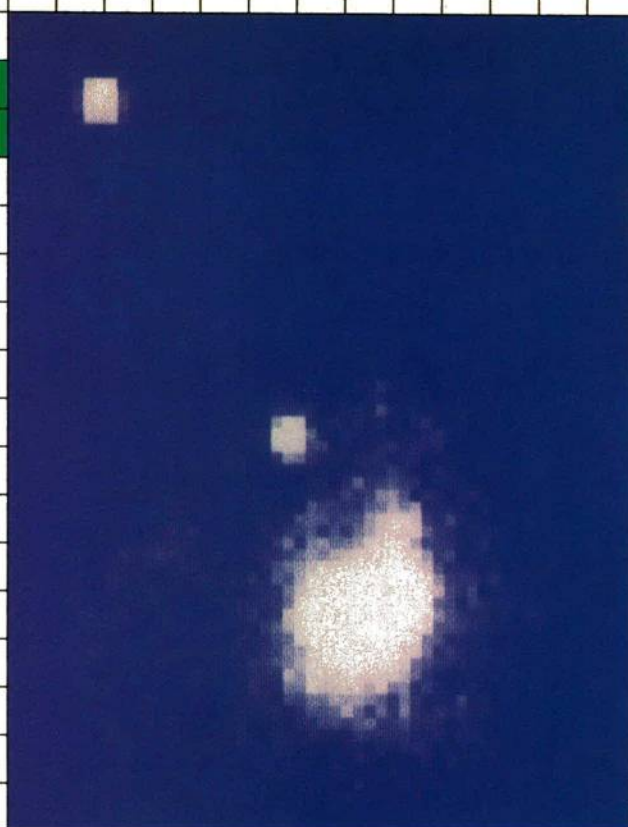
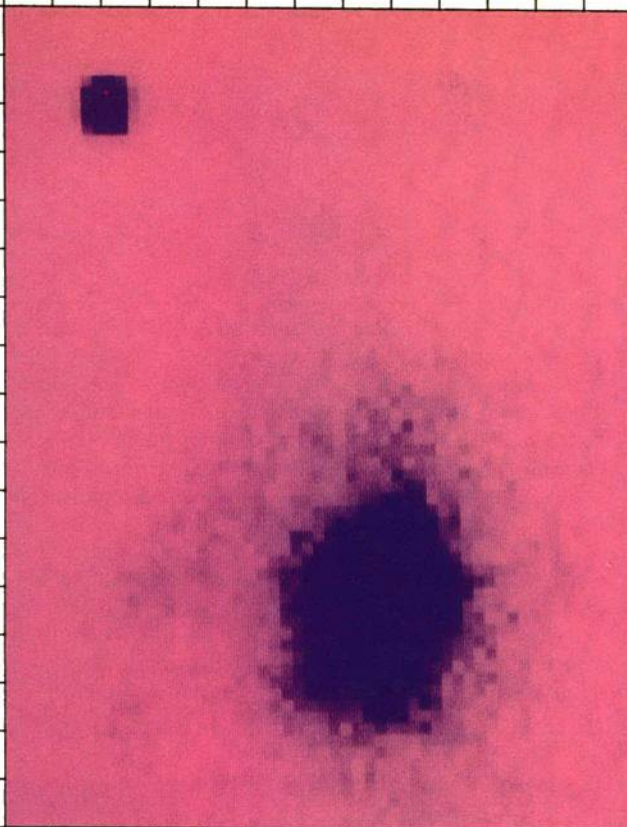
As the light from the supernova traveled through space, it was bright enough to be noticed by inhabitants of any galaxy it swept past. When the explosion first shook M-99, dinosaurs were enjoying their last few million years of existence on Earth and mammals were the size of chipmunks.

Frank Crawford, Peter Friedman, Rich Muller, Saul Perlmutter, Craig Smith, Richard Treffers, Jordin Kare, and James Graham — undertook the experiment in an era of decreasing federal science budgets and continually struggled to keep the experiment going.

For advice, the group sought out Colgate and Nobel Laureate Luis Alvarez of Berkeley. Alvarez is an expert at solving old problems with new technology. His Nobel Prize honors his work with an innovative detector to discover new elementary particles in the 1950s. Later he used cosmic-ray physics to "x-ray" Egyptian pyramids, searching for hidden chambers. He then applied nuclear physics to geology and demonstrated that an asteroid or comet may have struck Earth 65 million years ago, killing the dinosaurs.

Alvarez became interested in our project while browsing through a copy of *Aviation Week and Space Technology*. There he learned that the U.S. Ballistic Missile Defense Command operates a set of automated telescopes on Kwajalein Atoll in the Pacific to monitor American ballistic missile tests. The missiles, launched from Vandenberg Air Force Base in California, land in the water just off Kwajalein. During these tests the telescopes automatically track and record the missiles as they re-enter the atmosphere. But normally these telescopes sit idle. Sensing an opportunity, Alvarez wrote a memo to his colleague Rich Muller: "This looks like the telescope to do what Stirling Colgate wanted to do — see the first phases of a super-

The galaxy M-99 is an Sc-type spiral that sits on the far side of the Virgo Cluster. Some 70 million years ago a star exploded inside one of M-99's spiral arms, briefly outshining the entire galaxy. In May 1986 the light from this stellar explosion finally reached Earth and provided astronomers with valuable data on how stars end their lives. All photos courtesy University of California-Berkeley.



nova in another galaxy.”

Catching a supernova “on the rise” has always been a challenge. All but a few supernovae have been discovered after they attained greatest brightness. But a search that included regular viewing of certain galaxies could revolutionize the field by producing large amounts of data during the early stages of a supernova event. This might allow astronomers to understand how the energy of the star’s collapsed core is transferred to the outer envelope, what kind of matter is synthesized in different parts of the explosion, and what the fate of the neutrinos is.

A systematic supernova search sounded promising, and Muller pursued it with his contacts in the Air Force. The proposed experiment was straightforward — the supernova hunters would send a list of galaxy coordinates to scientists at Kwajalein and receive back tapes or satellite-relayed pictures of a few thousand galaxies per week. Then the astronomers would compare these pictures to old pictures and look for out-of-place stars.

After a year of consideration the project still seemed

feasible. Muller discussed the idea with Stirling Colgate at a conference and realized that a laboratory like Lawrence could provide assistance with this experiment. Muller decided to intensify the effort, recruit a team, and solicit funding.

The first step was appointing a team leader, and Muller asked me to take the assignment. I had arrived at Berkeley in October 1979, after I had received my doctorate from Harvard. I was looking for a way to get out of studying cosmic ray physics, and the search seemed like a good alternative. Alvarez warned me to be careful about the decision: “A scientist can only work on about five projects in his whole lifetime.”

I was excited by the experiment and, without too much consideration, signed on as the leader. We soon assembled a full group. Frank Crawford, a Berkeley physics professor, and Jordin Kare, a graduate student, joined the search. Besides making important contributions in the strategy and tactics of the search, Kare designed, built, and acquired much of the equipment and software we needed.

After a few months of analyzing the experiment, Muller and I realized that the original idea of using the Kwajalein telescopes wouldn’t work. The cameras mounted on the automated telescopes lacked the necessary sensitivity, and the Air Force didn’t have the flexibility to switch cameras back and forth every few days. Also, technology existed to detect supernovae five hundred times fainter than those the Air Force cameras could see. We knew we could do better somewhere else.

Our team hoped to use a small optical telescope and Berkeley’s expertise to automate this telescope to search a few thousand galaxies per night. The experiment would require three technological advances: an automated telescope, a very sensitive camera, and new image-processing software. We wanted to mount a state-of-the-art camera and have a computer compare new and old images as soon as it received new ones. Small, cheap computers and

We looked at images of the galaxy from the week before and found no light at the supernova’s position. We were so eager for a discovery that Muller was concerned about our judgment and warned us to be cautious. If our first supernova report turned out to be a false alarm, our credibility would suffer, and with it our future funding. Alternatively, if we waited too long, somebody else might discover the supernova.

This first photo on the opposite page depicts the inner region of M-99 on May 8, 1986. The second photo, taken on May 16, shows the same region with the supernova. The photo on this page is a composite of the first image subtracted from the second image; the supernova is the residual bright spot.

largely on the reports of the referees and the availability of money.

In our case, half of the referee reports were supportive: "The basic concept is excellent . . . A project of major importance . . . This kind of search is clearly the necessary way to proceed . . . The planning has been thoughtfully done." But other referees did not support the project. "Previous efforts have all failed . . . [There is a] good chance that these authors will not succeed . . . The authors are basically physicists with virtually no experience in optical astronomy."

Given the tight budgets, I could understand why the program manager chose to fund ideas more accepted than our project. Nevertheless, the situation was depressing. Without money there would be no supernova search.

We obtained temporary support from the Lawrence Berkeley Labs, where we kept building new circuits, writing computer programs, and writing new proposals. I made a trip to Washington to meet the people who held government purse strings. Muller used his influence to arrange appointments for me with program managers and their bosses in Washington. But after talking with governmental budget representatives, we were turned down. There would be no Washington money.

Without acceptance by the major funding agencies, we faced six years of funding problems. The future of my salary was always in grave doubt. Only the willingness of Lawrence Berkeley Labs to provide temporary "seed" money saved the experiment each year. In addition, Muller had recently won an award, which included a limited amount of unrestricted grant money he could devote to this project. This award money was my lifeblood: it rescued the group, bought a computer, fed my family, provided the expensive CCD, and supported graduate students.

The difficulty of funding a project often demoralizes young researchers. It led me to question the worth of such ventures. I was thirty years old, my wife was expecting a baby, and we could barely pay our bills. My academic salary threatened to disappear every six months. Most of my colleagues from graduate school had shown more sense than I had and had taken jobs in industry, making double or triple my salary. Alvarez remarked that he would have quit physics if he were in my shoes.

Launching the Project

Working at Berkeley, our team built a CCD camera and computer system. We could afford only one CCD chip — a delicate, \$6,000 integrated circuit that could be destroyed very easily. Nervously I inserted the chip into its socket one day, knowing that if I bent a pin or had too much stray electric charge on my hands, the experiment would be over. Other groups had destroyed chips, but they could afford to replace them.

Once we got the chip installed and working, Jordin Kare and his friend Shane Burns, a new graduate student, spent a year eliminating unexpected problems with the camera. We completed the nontrivial task of directly transferring an image from the CCD into the computer's memory without introducing false signals that would mask

recent developments in integrated circuits made telescope automation a realistic prospect. Telescope positioning sensors had dropped tremendously in price; we soon realized that the automation of the Kwaajalein telescopes was not unique.

The heart of our new home-built sensitive camera would be a charge-coupled device, or CCD. Today CCDs are easily available and relatively cheap, but in 1979 they were expensive and relatively rare. The heart of a CCD is an extremely light-sensitive chip that replaces the film used by ordinary cameras. A CCD image is comprised of a rectangular grid of 160,000 discrete elements called pixels.

A CCD requires a computer and image-processing techniques that reconstruct the digitally encoded image. Our minicomputer would aim the telescope toward the target galaxies, open the shutter, expose the CCD, and transfer the image into the computer's memory. The computer housed a fixed library of galaxy pictures, which were subtracted nightly from each new image. A supernova that had exploded since an old image was made would show up as a residual bright spot on the subtracted image.

The Search for Funding

In 1981 Muller and I began soliciting money for our project. Considering the scientific potential of the project, I expected few problems. Our plans to update and implement Colgate's search idea were met with excitement by nearly every professional astronomer I talked to. In these conversations the tone and demeanor of the astronomers indicated we were doing something important. One message I drew from such early exchanges was that government grant money would be available. I was poorly prepared for what happened.

After receiving a proposal, the program managers at a funding agency send the proposal out to academic peers (called referees) to assess the science, the team, and the likelihood of success. Decisions to fund a project are based



On December 23, 1986, Pennypacker's supernova search team confirmed its discovery of a supernova in the galaxy NGC-1667 in Eridanus. This pair of images shows NGC-1667 without the supernova on November 12, 1986 (left) and with supernova forty-one days later. A systematic search method of scanning several hundred galaxies per night resulted in this find just seven months after the M-99 discovery.

a weak signal from a supernova. For the image processing itself we wrote 100,000 lines of computer code, far more than I had anticipated.

In addition, Muller and I arranged to use a telescope built in southern California by a group of young astronomers collectively known as the Monterey Institute for Research in Astronomy, or MIRA. These astronomers were attempting to do something difficult even in times of good funding: striking out on their own. Unlike the established observatories, they were willing to let us modify their telescope for our experiment.

By the spring of 1983 the first light from the supernova in M-99 had reached the distance of Proxima Centauri, the closest star to us. That spring we produced our first galaxy image, which showed a beautiful spiral. It had taken us three years to produce one galaxy picture. Now the heat was on: we needed to look at thousands of galaxies each night to succeed. Thankfully, once our setup at the MIRA telescope was working, learning how to use it properly was relatively simple.

Now the problem became logistical. The trips to MIRA were devastating to our morale and wearing on our hardware. The long drive, unexpected bad weather, and broken equipment from the constant moving subverted our scientific energies.

We clearly needed a change. We reconsidered the Leuschner Observatory, run by the University of California astronomy department and located not far from Berkeley. Several years before, we had rejected Leuschner because it was not automated and because we feared the Bay area lights might interfere with faint supernovae.

Now Leuschner was an automated observatory. Our hardware could be easily adapted to the instrument, and lots of observing time was available. The weather at the telescope was relatively predictable. Less than a week after beginning to use the observatory, Kare and Burns went out and recorded fifty galaxy images in one night. Every observing session set a new record for galaxies observed per night. This early success at Leuschner gave us a burst

of new energy, and after four lean years we finally felt close to finding a supernova. I was proud to describe results to colleagues instead of the promises I had given with less and less conviction over the previous four years. The newfound suitability and accessibility of the Leuschner telescope was a lucky stroke.

Another break that improved the funding outlook soon followed: Muller proposed the Nemesis hypothesis. He and two colleagues suggested that the Sun has an unseen companion star, Nemesis, which orbits the Sun. Every 26 million years Nemesis would disturb the Oort cloud — the shell of cometary nuclei surrounding our Sun — causing catastrophic impacts on Earth and resulting in mass extinctions. Muller's theory was linked to Alvarez's ideas about how the dinosaurs died. Because it would explain many fundamental questions of evolution, the idea generated tremendous public interest. Perhaps life had evolved as it did because Nemesis had destroyed earlier species like the dinosaurs, leaving vacant niches for new life forms to fill. Though Nemesis had never been detected, Muller proposed that the supernova search, with only slight modifications, could contribute toward the search for Nemesis as well as continue to look for supernovae. We added a group of some three thousand red stars to the observing program, which gave us new sources of funding for both Nemesis and the supernova search.

The good luck brought by Nemesis soon soured, however. Nemesis threatened to extinguish our project as it had the dinosaurs because it occupied most of the group's time and almost all of our resources during the next year. Meanwhile, Kare and Burns, who had designed and built much of the equipment, graduated from Berkeley and left the project. They wrote Ph.D. theses describing their considerable efforts to create hardware and software but had no supernova data to show. We pushed on without them, but I called them constantly for advice on how to fix or maintain equipment they had designed or built.

By January 1986 light from the M-99 supernova had entered the Oort cloud. As a reference against which we could compare each new galaxy image, we had collected two thousand pictures of galaxies without supernovae. We needed a supernova, but the automated data analysis scheme wasn't giving us one. Muller suggested we visually compare the new and old galaxy images rather than rely on the computer. So we started a new process of examining the images. Each new image first underwent

analysis by computer software. Then the human eye with its unmatched ability for image recognition performed the last search.

Supernova!

When we looked at M-99 on May 8, 1986, we saw no supernova. On the night of May 16, we looked again. In a routine scan of galaxies that night, the light that had traveled for 70 million years struck our CCD and was recorded on magnetic tape. The data journeyed through our software over the weekend. On Monday Frank Crawford scanned the subtracted galaxy images. He had scanned about forty galaxies before finding something interesting. When he examined the new image of M-99, he found that a bright spot appeared near one of the galaxy's arms. The reference image showed no star at the new star's position. He had found the supernova.

Crawford showed me the candidate and within five minutes he convinced me we might have something genuine. Within an hour everybody in the group was hovering over the image-display hardware, manipulating the contrast levels to bring out the best picture possible. We were wild with excitement.

After a few minutes of pure exhilaration a serious question arose: should we announce our discovery? Our eagerness to let the world know was tempered by the knowledge that electronic artifacts sometimes produced by CCDs or other astrophysical objects could produce an image that looked like a supernova. Should we call the International Astronomical Union (IAU), the organization responsible for keeping track of supernovae and other astronomical phenomena? Or should we wait until we had made a confirming observation?

We looked at images of the galaxy from the week before and found no light at the supernova's position. We were so eager for a discovery that Muller was concerned about our judgment and warned us to be cautious. If our first supernova report turned out to be a false alarm, our credibility would suffer, and with it our future funding. Alternatively, if we waited too long, somebody else might

hydrogen atom. We had our first supernova!

After the years of strain I simply could not believe it. Later in California the clouds parted so our observer at Leuschner could take a quick look at the supernova. He found it to be almost as bright as M-99 itself.

I called Muller, and around midnight we agreed on the wording of a telegram to be sent to the IAU. I called the IAU again the next morning, learned our supernova had been given the designation 1986i, and discovered that nobody else in the world had seen it. In fact, most other searches would have missed Supernova 1986i because it was hidden in one of the galaxy's spiral arms. Only a search with sensitive detectors like ours could have found it.

The first light from the supernova had passed through our solar system. Hardly pausing to celebrate, we pushed on to get other observatories to look at our supernova. For the next month I was on the phone frequently, arranging for astronomers at other observatories to take a spectrum of our object and watch the explosion unfold. The supernova in M-99 was bright enough for astronomers to take a high-quality spectrum in a few minutes.

In the early days of our experiment we envisioned sitting on our first supernova, quietly making observations by ourselves, and publishing the exciting results with the Berkeley team as the sole authors. After our discovery we quickly changed our approach: we wanted to extract as much science as possible from this supernova. With the supernova explosion changing on a time scale of hours, enlisting the cooperation of other scientists became imperative. The result is that our spectra trace the behavior of the hydrogen emission and the temperature changes better than that for any other supernova until Supernova 1987A in the Large Magellanic Cloud. In addition, the spectra precisely show the velocity of the explosion throughout its cycle. We have watched the star grow in brightness and then fade.

As we begin the long task of analyzing the data on this supernova, we are learning many details of its history. This explosion is in some ways radically different from others. In the early stages it showed greater than average light from hydrogen atoms. While we are analyzing data from our first explosion, we are now upgrading the search to a much more powerful computer and CCD system that will allow us to see fainter, younger, and much more distant supernovae.

The data from the M-99 explosion and other supernovae to come will help us understand the origin of the elements and probe the geometry of the universe. For this task we need hundreds more supernovae. Now that our experiment is working, we can easily search five hundred galaxies per night, and soon we will monitor one thousand per night.

Now the first light from the M-99 supernova is racing beyond our solar system toward the constellation Cetus. Meanwhile, in one of the thousand nearest galaxies, another star has exploded. But we don't know which star or which galaxy. During the next few months our team's automated system will search that galaxy a few days after its light arrives on Earth. We will then see our second supernova's first light.

The data from the M-99 explosion and other supernovae to come will help us understand the origin of the elements and probe the geometry of the universe. For this task we need hundreds more supernovae. Now that our experiment is working, we can easily search five hundred galaxies per night, and soon we will monitor one thousand per night.

discover the supernova. We finally decided to play it "in-between" and wait for at least one confirming observation. We didn't know if the sky above Leuschner would be clear, so I called several observatories and found an astronomer at Kitt Peak willing to look at M-99 that night.

At 10 p.m. the sky over Berkeley was not clear enough to observe. But I got a call from the Arizona astronomer. The spectral plate he made of the object showed that the object was clearly a supernova and that we had caught it early. The spectrum showed that the star was emitting tremendous amounts of light at the H-alpha line of the

In 1978 Carl Pennypacker earned his Ph.D. in astronomy from Harvard University for his thesis entitled "Infrared Studies of Pulsars." He is currently an associate research physicist at the Lawrence Berkeley Laboratories in Berkeley, California. The author wishes to thank Ronald Kahn for assistance in preparing this article.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH



Spiral Galaxy M-99 (NGC 4254) in Coma Berenices. Spiral structure detail can be seen visually for this 10th magnitude galaxy. 40 minute photo by Dr. Jack Marling using hypered 2415 film, 24" 1/6 telescope and LUMICON Giant EASY-GUIDER.

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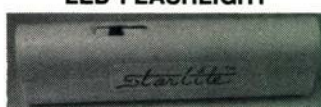
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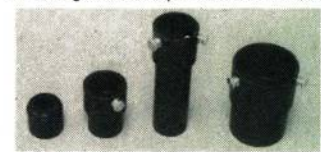
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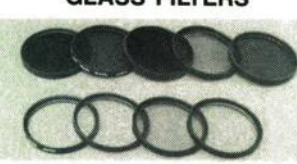
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LUMICON NGC NOTES

OBJECT DESCRIPTION: NGC No., Name, Object Type, Location

VIEWING CONDITIONS: Date, Time, Seeing, Observer's Name, Observing Site, Telescope Type, Filter Type, Eyepiece, Magnification

ADDITIONAL REMARKS & NOTES: (Use backside of card for additional notes)

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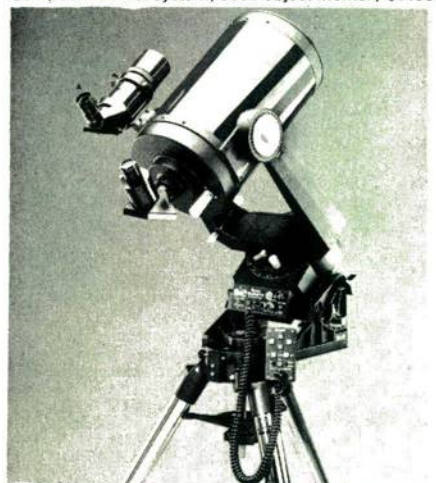
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PHOTOGRAPHY ACCESSORIES

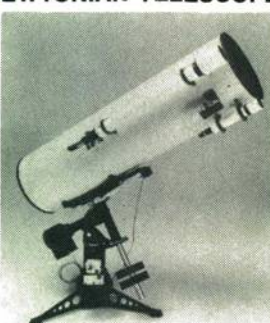
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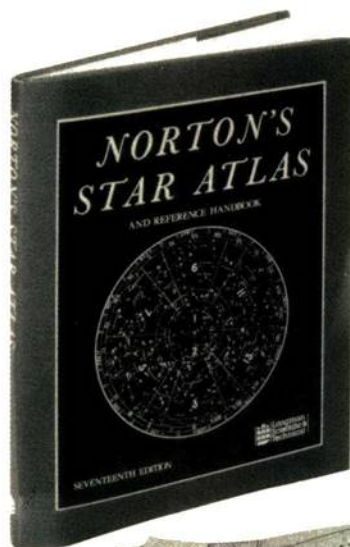
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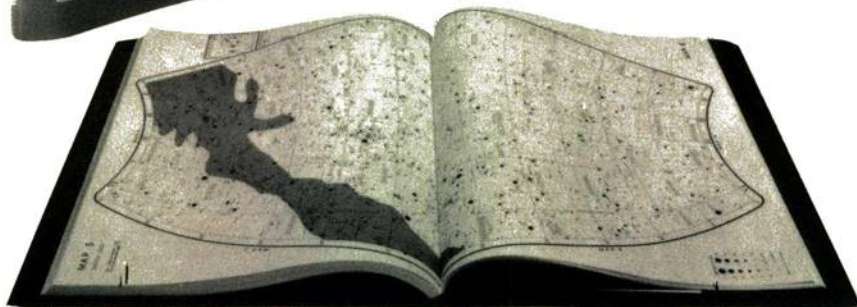
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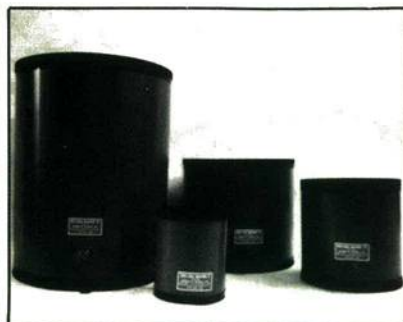
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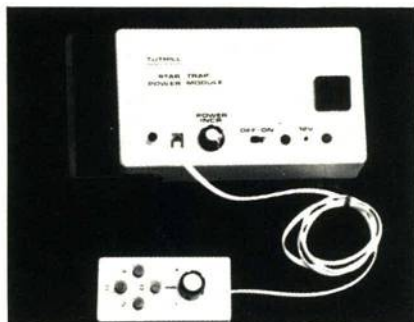
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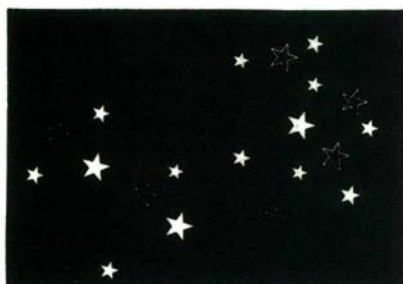
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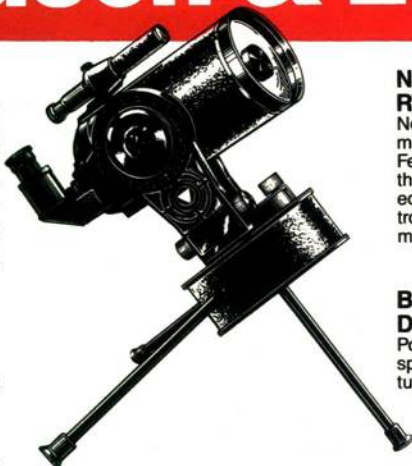
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Above left: One of the richest starfields in the northern Milky Way contains bright open cluster M-52 (upper left) and emission nebula NGC-7635. NGC-7635 is known as the "Bubble Nebula" because of its distinctive shape. Photo by John Kerns.

Left: Surrounding the 5th-magnitude star Phi (ϕ) Cassiopeiae is the bright, scattered cluster NGC-457. This group of eighty stars, called the "Owl Cluster," shines at magnitude 6.4. Photo by Jack Newton.

Top: Holding twenty-five stars in an area spanning 6', the cluster M-103 has a magnitude of 7.4. It is visible in binoculars as a fuzzy patch of gray-green light some 3' across. Photo by Jack Newton.

Above: One of the best open clusters for small telescopes is NGC-7789, a huge grouping of three hundred stars. Although none of its stars shines brighter than magnitude 10.7, the cluster shines as brightly as a magnitude 6.7 star. It is visible in a 3-inch scope as a large cloud of pale nebulosity spotted with tiny stars. Photo by Lee C. Coombs.

Cassiopeia

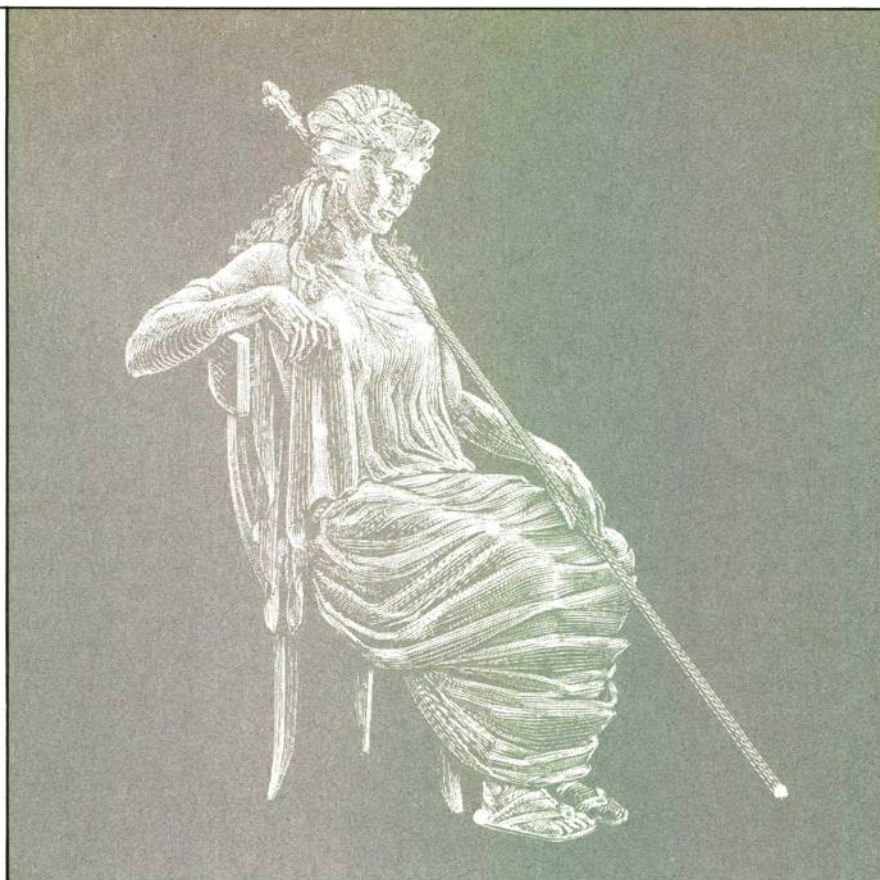
Cas Cassiopeiae

Smack-dab in the middle of the northern Milky Way, **Cassiopeia** the Queen is a constellation rich in galactic deep-sky wonders. Cassiopeia, a great W-shaped asterism of five bright naked eye stars, contains four bright nebulae suitable for small telescopes and nine bright examples of open star clusters. The constellation also holds three unusual galaxies, two of which are dwarf ellipticals physically connected to the M-31 system in Andromeda.

The brightest star cluster in Cassiopeia is **NGC-457**, located about 2° south-southwest of the variable star Delta (δ) Cassiopeiae. This cluster contains at least eighty stars and has a total magnitude of 6.4, which make it barely visible to the naked eye as a small patch of fuzzy light. Phi (ϕ) Cassiopeiae, a 5th-magnitude star visible to unaided eyes, appears inside this cluster but is most likely a foreground object. Another bright star, HD 7902, is a 7th-magnitude beacon immediately west of Phi. HD 7902 is probably not a cluster member either, but these two bright stars help make NGC-457 a beautiful sight in backyard telescopes.

The brightest stars in NGC-457 are arranged in distinct lines and curves, outlining the apparent form of an owl. The two bright field stars, Phi and HD 7902, represent the bird's eyes. A rectangular clump of 9th- and 10th-magnitude stars traces a body, and scattered curving rows of fainter stars outline an owl's wings, which extend roughly north-south. Because of its shape NGC-457 has acquired the nickname "the Owl Cluster."

This arrangement of stars makes NGC-457 a particularly pretty sight with just about any optical instrument. Binoculars show the cluster as a fuzzy patch of light spreading west and slightly north and south of the bright pair of stars. A 3-inch



Keith Ward

refractor at moderate power resolves the group into two dozen faint specks of white light. An 8-inch telescope shows NGC-457 as a group of several dozen stars sprinkled across a diameter of 13'. This aperture also clearly shows that the brightest cluster member, a magnitude 8.6 star, has a distinctly ruddy orange color. Although NGC-457 was not included in the Messier catalog and therefore isn't as well known as many nearby open clusters, a look at this group of stars should convince you it is one of the finest in the northern sky.

Only 1° northeast of Delta Cassiopeiae is the fine open cluster **M-103** (NGC-581). M-103 is a magnitude fainter than NGC-457 and contains twenty-five stars in an area spanning 6'. This cluster's brightest star glows dimly at magnitude 10.6, some five times fainter than the brightest member of NGC-457. Although M-103 isn't as large or as bright as the Owl Cluster, it is an impressive group of stars. A 4-inch telescope shows M-103 as a fan-shaped group containing four bright stars between 7th and 9th magnitude and one 8th-magnitude orange star. Larger telescopes show myriad fainter stars in the cluster and the surrounding starfield.

Continue in a line from Delta Cassiopeiae through M-103 and extend the line another degree to open cluster **Trumpler 1**. This cluster was named for American astronomer Robert Trumpler, who meticulously studied star clusters throughout

much of the twentieth century. Trumpler 1 consists of twenty stars that are magnitude 9.6 and fainter and cover 4.5' of sky. The cluster's total magnitude is 8.1, which makes it faint but visible in binoculars. Small telescopes trained on Trumpler 1 reveal a sprinkling of faint stars that on nights of average transparency appears as little more than an increase in density of the rich Cassiopeia Milky Way.

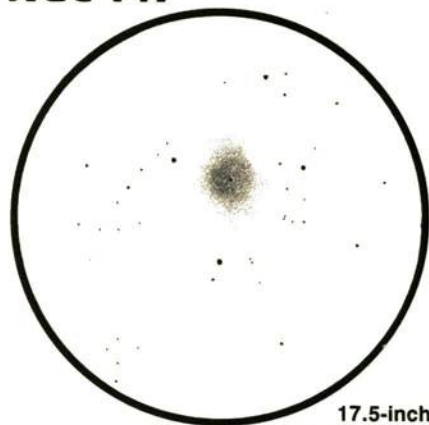
A more impressive cluster lies 3° southwest of the bright star Beta (β) Cassiopeiae, the westernmost star in Cassiopeia's W-shaped asterism. **NGC-7789**, one of the richest open clusters in the sky, consists of at least three hundred stars of magnitude 10.7 and fainter in an area half the size of the Full Moon. NGC-7789 can be found by sweeping southwest of Beta Cassiopeiae to Rho (ρ) and Sigma (σ) Cassiopeiae, a pair of 5th- and 6th-magnitude stars separated by 2°. NGC-7789 lies midway between these stars.

Teoscopically NGC-7789 is a treat. Binoculars show it as a gray cloud of haze of uniform brightness. A 6-inch telescope shows a cloud of nebulosity over 10' across peppered with dozens of faint stars. A large backyard telescope in the 12- to 18-inch range shows the cluster as a nebulous disk of light with over one hundred visible stars that appear like a sparsely populated globular cluster.

About 3° northeast of Beta Cassiopeiae is the open cluster **NGC-103**. This group of thirty stars glows at magnitude 9.8 and

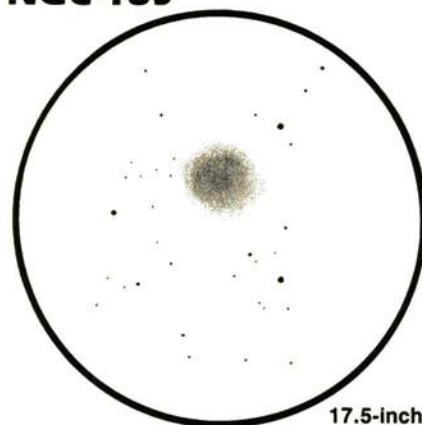
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NGC-147



17.5-inch
f/4.5 reflector
71x

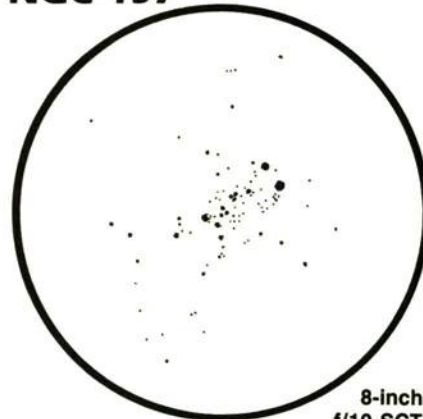
NGC-185



17.5-inch
f/4.5 reflector
71x

Sketches by David J. Eicher

NGC-457



8-inch
f/10 SCT
50x

covers 5' of sky. NGC-103 is unimpressive in binoculars because its brightest stars are so faint. In a 6-inch reflector, however, the group appears as a misty cloud sprinkled with a number of 12th- and 13th-magnitude stars. One-and-a-half degrees south-southeast of NGC-103 is the more impressive cluster **NGC-129**. This sparkling array of thirty-five bright stars offers a fine contrast to NGC-103. NGC-129's diameter of 21' and total magnitude of 6.5 make the cluster a beau-

tiful sight in any telescope.

Two large, scattered clusters lie in the southeastern corner of Cassiopeia about 4° north of the Double Cluster in Perseus. **IC 1805** is a bright group of forty stars spread across 22'. The brightest stars of this group shine at magnitude 8, which makes the region a fine area for scanning with a pair of binoculars. About 2.5° southeast of IC 1805 is the smaller cluster **IC 1848**. This object has the same magnitude as IC 1805 but contains fewer stars and covers only half as much sky. Both of these clusters are surrounded by a network of emission nebulosity barely visible to observers with large backyard telescopes.

At the opposite end of the constellation lies **M-52** (NGC-7654), a 7th-magnitude group of one hundred stars located 1° south of the bright star 4 Cassiopeiae. Along with NGC-457 and NGC-7789, M-52 is among the best clusters in the northern Milky Way. Its stars shine at magnitude 8.2 and fainter and cover 13' of sky, which is about one-third the size of the Moon's disk. Small telescopes show M-52 as a rich, bright mass of dozens of stars.

One degree southwest of M-52 is the unusual emission nebula **NGC-7635**, the Bubble Nebula. This object is an extremely faint emission nebula measuring 15' by 8' across. The brightest part of this object is bubble-shaped, hence the nickname. Observers with 8-inch scopes may see traces of the Bubble nebulosity on exceptionally dark nights.

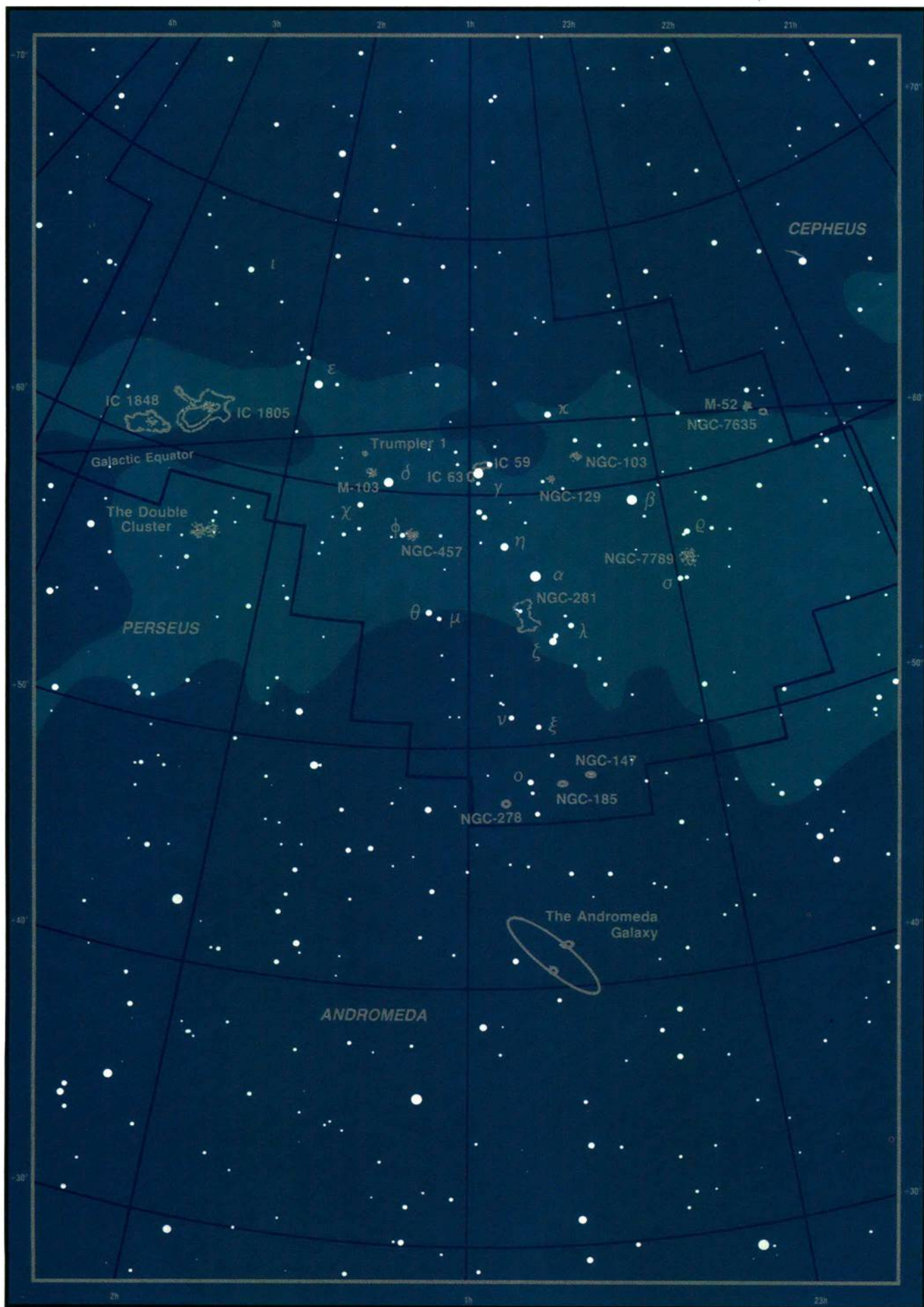
Another faint emission nebula lies some 2.5° east of the star Alpha (α) Cassiopeiae. **NGC-281** is a large cloud of low surface brightness covering an equilateral triangle of 7th-magnitude stars separated by about 30'. To see this nebula you'll need to use a low-power eyepiece and perhaps a nebula filter on a 10-inch or 12-inch telescope.

Fainter yet are two nebulae surrounding the bright star Gamma (γ) Cassiopeiae. Both **IC 59** and **IC 63** have extremely low surface brightnesses. And 3rd-magnitude Gamma Cassiopeiae, which is invariably in the field of view while you try to observe them, doesn't help viewing. Try using a large-aperture scope, a good nebula filter, and an occulting bar — a small piece of metal — over the eyepiece to block the bright star but not the field of view around it.

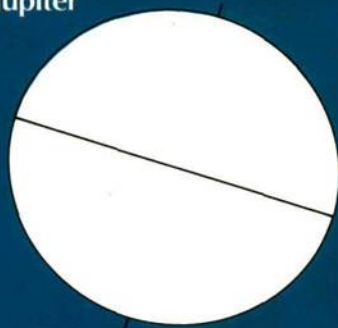
At the extreme southern end of Cassiopeia lie three galaxies, two of which are members of our Local Group of galaxies. Located about 8° north of the Andromeda Galaxy, **NGC-147** and **NGC-185** are distant satellite galaxies revolving around the Andromeda spiral. Each is a dwarf elliptical galaxy, and although both are low-surface brightness objects, each is visible with a 6-inch telescope under good conditions. NGC-147 shines at magnitude 9.3 and measures 12.9' by 8.1'. NGC-185 is a magnitude 9.2 galaxy spanning 11.5' by 9.8'. Both galaxies appear as ghostly patches of gray light in backyard telescopes. Three degrees southeast of NGC-185 is the compact elliptical **NGC-278**. This 11th-magnitude galaxy measures 2.2' by 2.1' and has a bright, compact core.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★	
NGC-103		○	0h 25.3m	+61°21'	9.8	5'	30	12.3	○ Open Star Cluster
NGC-129		○	0h 29.9m	+60°14'	6.5	21'	35	8.6	□E Emission Nebula
NGC-147		○	0h 33.2m	+48°30'	9.3	12.9'x 8.1'			□ER Emission and Reflection Nebula
NGC-185		○	0h 39.0m	+48°20'	9.2	11.5'x 9.8'			○ Elliptical Galaxy
NGC-278		○	0h 52.1m	+47°33'	10.9	2.2'x 2.1'			
NGC-281		□E	0h 52.8m	+56°36'	—	3.5'x 30'			
IC 59		□ER	0h 56.7m	+61°04'	—	10'x 5'			
IC 63		□ER	0h 59.5m	+60°49'	—	10'x 3'			
NGC-457		○	1h 19.1m	+58°20'	6.4	13'	80	8.6	
NGC-581	M-103	○	1h 33.2m	+60°42'	7.4	6'	25	10.6	
Trumpler 1		○	1h 35.7m	+61°17'	8.1	4.5'	20	9.6	
IC 1805		○	2h 32.7m	+61°27'	6.5	22'	40	7.9	
IC 1848		○	2h 51.2m	+60°26'	6.5	12'	10	7.1	
NGC-7635		□E	23h 20.7m	+61°12'	—	15'x 8'			
NGC-7635	M-52	○	23h 24.2m	+61°35'	6.9	13'	100	8.2	
NGC-7789		○	23h 57.0m	+56°44'	6.7	16'	300	10.7	

N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star, (...) indicates many fainter.



Jupiter



Mercury



1st



9th

Venus



15th

Mars



Saturn



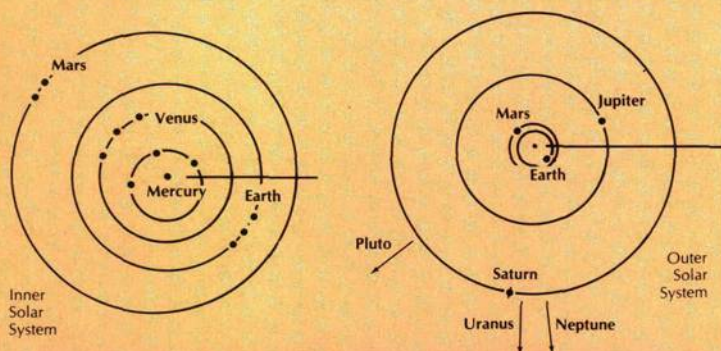
Uranus



Neptune



	Date	Mag.	Angular Size	% Illum.	Distance (AU)		Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
					from: Earth	Sun				
Sun	1	-26.7	31.6'	—	1.015	—	—	128°14.7'	8h 43.3m	18°09.8'
	15	-26.7	31.6'	—	1.013	—	—	141°39.5'	9h 36.8m	14°14.1'
	31	-26.7	31.7'	—	1.010	—	—	157°04.7'	10h 35.8m	8°51.1'
Mercury ♀	1	-0.6	6.5"	61%	1.033	0.324	32°20.2'	110°30.1'	7h 27.3m	21°19.1'
	15	-1.7	5.1"	97%	1.312	0.321	118°07.2'	136°15.6'	9h 16.8m	17°30.2'
	31	-0.9	5.0"	95%	1.360	0.407	192°48.6'	167°13.0'	11h 15.0m	6°09.0'
Venus ♀	1	-3.9	9.7"	99%	1.720	0.719	113°27.3'	122°18.0'	8h 19.0m	20°29.0'
	15	-3.9	9.7"	100%	1.729	0.718	136°11.5'	139°34.1'	9h 29.5m	16°06.8'
	31	-3.9	9.7"	100%	1.726	0.719	162°11.5'	160°37.1'	10h 45.9m	9°21.9'
Mars ♂	10	1.8	3.5"	100%	2.670	1.663	144°53.7'	142°01.6'	9h 39.1m	15°15.5'
	20	1.7	3.5"	100%	2.676	1.665	149°16.3'	148°23.1'	10h 03.7m	13°06.3'
Jupiter ♃	15	-2.6	43.7"	99%	4.484	4.953	18°45.3'	29°50.3'	1h 53.2m	10°05.5'
Saturn ♄	15	0.4	17.1"	100%	9.595	10.033	259°53.3'	254°44.1'	16h 54.4m	-21°08.1'
Uranus ♅	15	5.6	3.8"	100%	18.680	19.224	265°25.8'	263°10.2'	17h 29.6m	-23°25.0'
Neptune ♆	15	7.9	2.3"	100%	29.523	30.233	276°54.0'	275°46.2'	18h 24.6m	-22°17.3'
Pluto ♇	15	13.7	0.1"	100%	29.906	29.682	219°20.7'	217°39.0'	14h 41.5m	1°14.9'



Moon Data

First Quarter.....Aug. 2 at 19h24m
 Full Moon.....Aug. 9 at 10h17m
 Last Quarter.....Aug. 16 at 8h25m
 New Moon.....Aug. 24 at 11h59m
 First Quarter.....Sept. 1 at 3h48m
 Full Moon.....Sept. 7 at 18h13m
 Perigee: Aug. 8 at 19h20m UT...357,643 km
 Apogee: Aug. 21 at 13h37m...406,126 km



During a 2-minute guided exposure on August 29, 1986, a brilliant meteor flashed across the sky and was recorded in this image. Photo by Kenneth Paul Fye, who used a 50mm f/1.8 lens and Ektachrome 400 film.

Mercury

During the first week of August, Mercury is visible low in the northeastern sky just before sunrise. The planet has passed greatest elongation and is moving toward superior conjunction on August 20. In a telescope at medium or high magnification Mercury appears as an ivory-colored, gibbous disk about 6" across. (Its low elevation may cause poor seeing, however.)

About August 10, you will lose sight of Mercury as it sinks into the morning twilight. It will remain hidden in the Sun's glare until the middle of September, when it will reappear low in the west after sunset.

Venus

Venus is at superior conjunction on August 23 and will be out of view until late September or early October.

Mars

Mars is too close to the Sun to be seen this month; conjunction comes on August 25.

Minor Planets

1 Ceres (magnitude 7.8) lies almost stationary in southern Scorpius. Its positions:

1st: 17h 24m 44s, $-27^{\circ} 20.8'$

10th: 17h 23m 31s, $-27^{\circ} 33.6'$

20th: 17h 24m 41s, $-27^{\circ} 46.7'$

30th: 17h 28m 23s, $-27^{\circ} 59.0'$

Ceres sets around 11 p.m. local daylight time on the 15th.

2 Pallas (9.7) is moving southeast in Serpens Caput. It passes 38' north of the magnitude 3.7 star Beta (β) Serpentis on August 21. Pallas' positions:

1st: 15h 34m 49s, $19^{\circ} 42.1'$

10th: 15h 38m 58s, $18^{\circ} 06.1'$

20th: 15h 45m 06s, $16^{\circ} 19.4'$

30th: 15h 52m 41s, $14^{\circ} 34.2'$

Pallas sets about 2 a.m. local daylight time at mid-month.

3 Juno (8.7) is at opposition on August 23. It is moving retrograde in central Aquarius. Its positions:

1st: 22h 14m 26s, $-1^{\circ} 03.7'$

10th: 22h 08m 54s, $-2^{\circ} 04.0'$

20th: 22h 01m 26s, $-3^{\circ} 30.1'$

30th: 21h 53m 27s, $-5^{\circ} 10.5'$

Juno is visible all night.

4 Vesta (8.4) is moving eastward in western Gemini. Its positions:

1st: 6h 17m 33s, $21^{\circ} 14.5'$

10th: 6h 33m 11s, $21^{\circ} 13.2'$

20th: 6h 50m 10s, $21^{\circ} 05.7'$

30th: 7h 06m 38s, $20^{\circ} 52.6'$

Vesta rises about 2:30 a.m. local daylight time on the 15th.

8 Flora (8.5) is retrograding in Capricornus. On the 6th, it will lie 18' south of the magnitude 4.7 star Kappa (κ) Capricorni and on the 13th, it passes 37' south of Epsilon (ϵ) Capricorni, also at 4.7 magnitude. Two evenings later Flora lies south

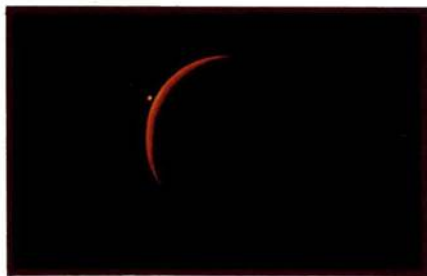


Satellites of Jupiter

7h00m UT

1	IJEC	• • • • •	16	GJIEC	• • • • •
2	GJIEC	• • • • •	17	GEIJC	• • • • •
3	GEJJC	• • • • •	18	GEJJC	• • • • •
4	GIECJ	• • • • •	19	JGIEC	• • • • •
5	CJIGE	• • • • •	20	IJECG	• • • • •
6	CIEJG	• • • • •	21	ECJIG	• • • • •
7	CEJIG	• • • • •	22	CIJEG	• • • • •
8	CIJGE	• • • • •	23	CGJIE	• • • • •
9	CGJIE	• • • • •	24	CGEIJ	• • • • •
10	CGEIJ	• • • • •	25	CGEJI	• • • • •
11	CGEIJ	• • • • •	26	CJE	• • • • •
12	CJGIE	• • • • •	27	CIJEG	• • • • •
13	IJCG	• • • • •	28	ECJIG	• • • • •
14	EJIGC	• • • • •	29	IJECG	• • • • •
15	IJGEC	• • • • •	30	GJIEC	• • • • •
			31	GEIJC	• • • • •

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



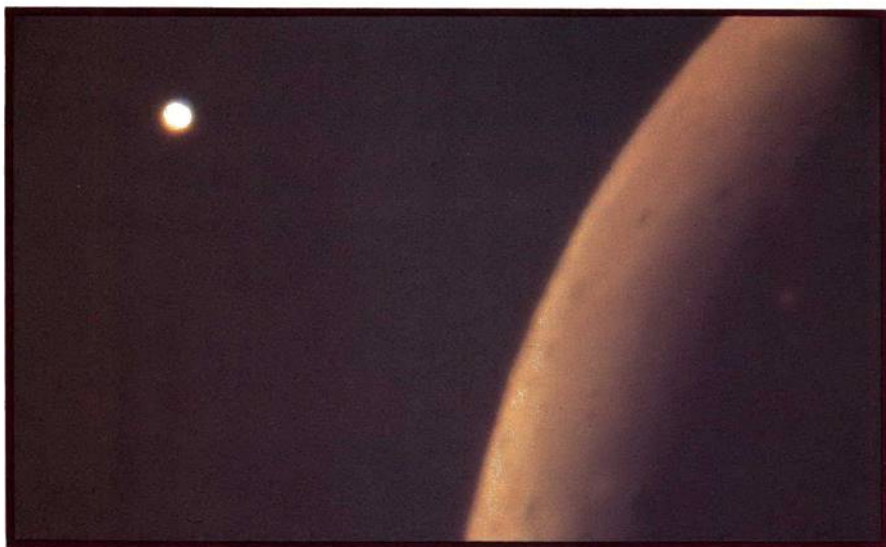
On the morning of April 25, 1987, the Moon occulted Venus for observers in Central America, eastern parts of North America, Greenland, and Iceland. From Pensacola, Florida, Venus disappeared behind the Moon's disk at around 5:08 a.m. CDT. Shortly beforehand, Steve Stanford made this series of three shots showing Venus approaching the lunar limb. The fourth photo shows Venus in twilight an hour and five minutes later, after it reappeared from behind the Moon. Stanford used a 5-inch f/10 SCT and Fujichrome 100 film push processed to ISO 200.

of 37 and 38 Capricorni, 6th- and 7th-magnitude stars aligned north and south. Flora's positions:

1st: 21h 47m 24s, $-18^{\circ} 21.3'$
 10th: 21h 39m 38s, $-19^{\circ} 40.0'$
 20th: 21h 30m 04s, $-21^{\circ} 03.6'$
 30th: 21h 20m 59s, $-22^{\circ} 13.1'$

At opposition on August 14, Flora rises at sunset and is visible all night.

To locate a minor planet, plot its positions for each date (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas*



2000.0 or *Uranometria 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Although Jupiter is visible by midnight, its low elevation at that time will produce unavoidably turbulent seeing. To get a clearer view, set your alarm clock for one hour before sunrise. As morning twilight brightens, Jupiter will be about 60° above the southern horizon.

If you store your telescope indoors, set it outside thirty minutes or more before you observe so it can cool to match the ambient air temperature. Then collect your eyepieces, filters (if you have them), and notebook. Locate Jupiter high in the south and aim your scope toward it.

Looking in a low-power eyepiece, you'll see a small, oval disk flanked by several of the Galilean moons. As you increase the magnification, the moons will slip out of the field while the disk grows larger. Dark belts and light zones will reveal themselves and show detail. At some point, however, you'll notice that increasing the magnification only makes the viewing worse: the increased detail given by higher eyepiece powers is offset by a softer image. When you find this trade-off point, which will vary from night to night, reduce the magnification a little and then settle down to enjoy the view.

Saturn

It's a safe bet that more people have been turned on to astronomy by looking at Saturn than by looking at anything else. Why not use Saturn's convenient placement in the evening sky this month to introduce the hobby to some nonastronomer friends? Place your telescope outside as soon as the Sun goes down. Because Saturn is near Antares, it has a relatively low elevation. This may mean you will have to find a special viewing spot with a low horizon.

Above: This close-up photo of the occultation was made with the 31-inch f/7 reflecting telescope at Warren Rupp Observatory in Ohio. Robert Bunge placed a camera against the telescope's eyepiece lens and exposed for 1/4-second on Ektachrome 100 film.

Opposite page: Steve House's photograph of the Moon's terminator takes this month's \$100 "Best Astrophoto" award. House used a 10-inch f/5 reflector, afocal projection, and Tri-X film. He copied the negative onto Tech Pan 2415 to increase contrast.

For many neophytes the most exciting view of Saturn comes at medium to low power — enough to show Saturn's rings clearly and include Titan. After your friends have marveled a while, slip in a high-power eyepiece for a quick tour of the Saturnian system. Show off the Cassini Division, the crepe ring, and Titan. But don't overdo it. Remember, what excites you is just unfamiliar fuzzy stuff to newcomers. Finish with a reprise of the overall view. Send them away remembering a tiny jewel-like Saturn adrift in an inky black sky.

Uranus

Uranus presents a featureless blue-green disk that measures 3.8" across. It is at magnitude 5.6 and lies $2\frac{1}{2}^{\circ}$ northeast of Theta (θ) Ophiuchi, a magnitude 3.3 star. Medium magnifications will show its disk as nonstellar. (For a finder chart see the January 1987 issue, page 108.)

Neptune

Neptune, like Uranus, lies in the evening sky, where it is moving slowly retrograde 3° north and $30'$ west of 2.2-magnitude Lambda (λ) Sagittarii. Neptune's 8th-magnitude disk spans 2.3" and appears pale gray at medium or high magnification. (A finder chart is in the January 1987 issue.)

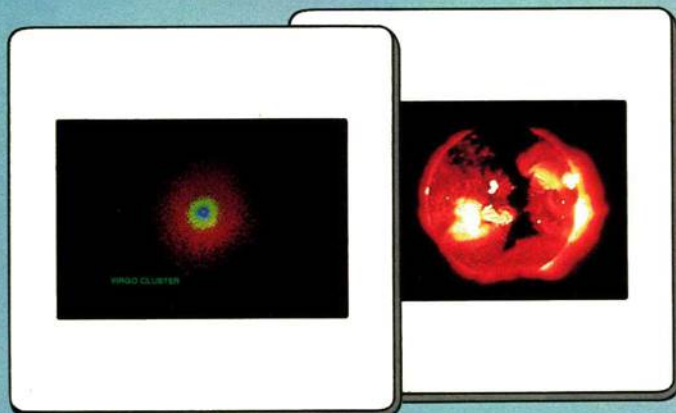
Pluto

Throughout August, Pluto lies in the constellation Virgo and is too close to the Sun to be visible.



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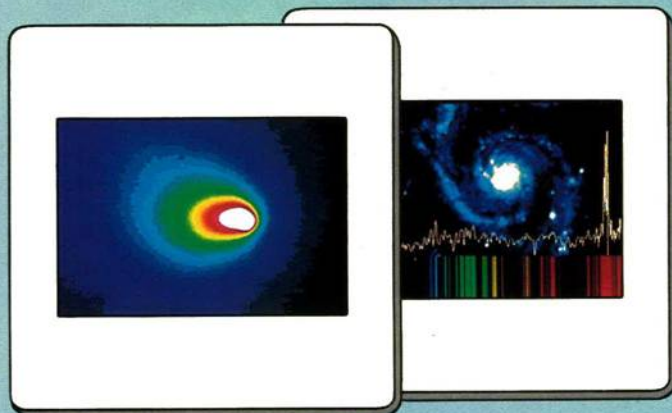
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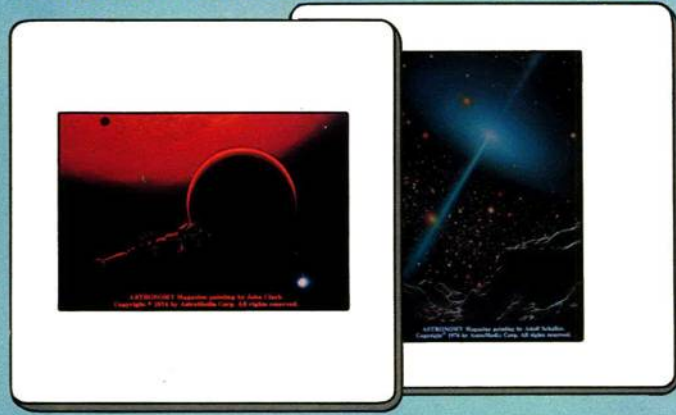
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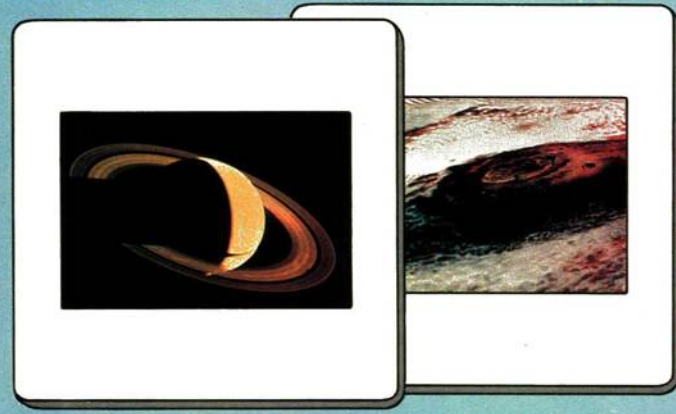
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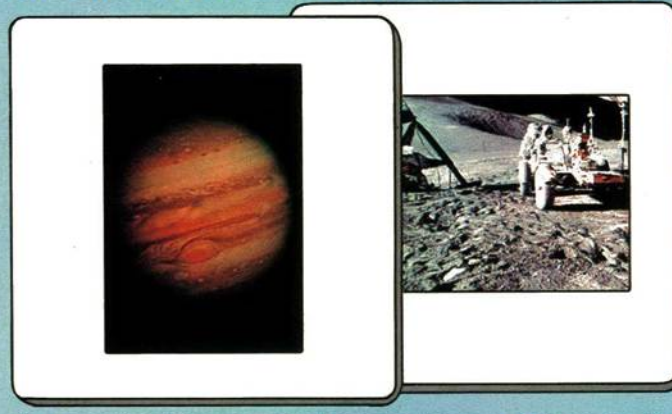
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